COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Engineering Library

AUGUST, 1941

AUG 21 1941

Furnace at East Wells Street Station, Milwaukee, after 4,656 hr of continuous operation and 15,916 hr since installation

Huge Power Expansion Planned ▸

Graphical Combustion Calculations ▸

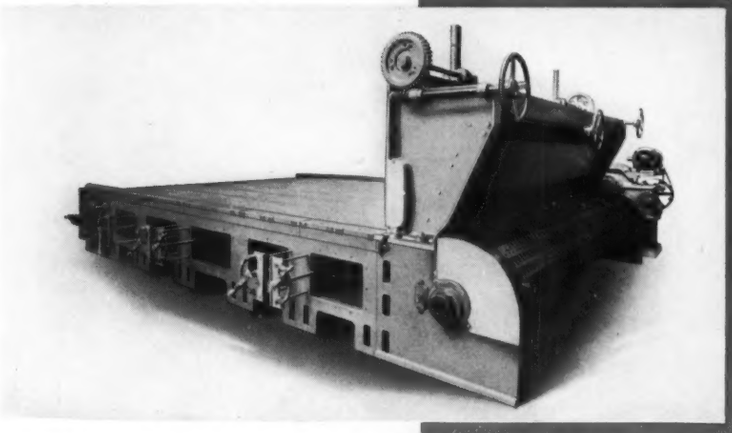
WHEN CONDITIONS CALL FOR CHAIN OR TRAVELING GRATE STOKERS

YOU CAN TURN TO

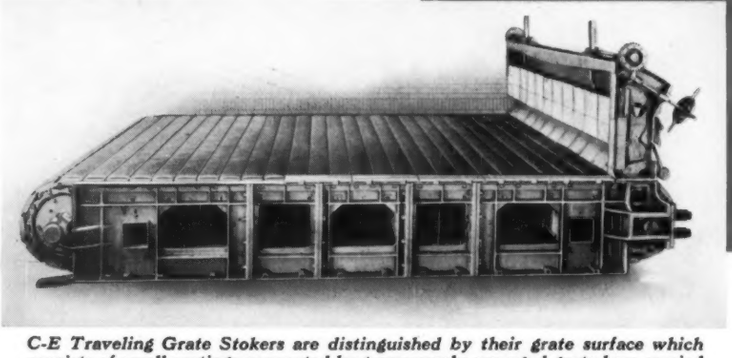
C-E

FOR

ANY TYPE
ANY SIZE



C-E Chain Grate Stokers have a grate surface which consists of a number of small link castings held together by through rods to form a continuous, flexible chain. Special driving links, located at intervals across the width of the stoker, engage a series of driving sprockets carried on the front shaft.



C-E Traveling Grate Stokers are distinguished by their grate surface which consists of small castings supported by transversely arranged grate bars carried by sprocket-driven chains located between the stoker side frames.

Here's another classification of stokers that bears out C-E's reputation as "Headquarters for all Types of Fuel-Burning Equipment."

Among *Traveling Grate Stokers,* C-E offers types to serve the approximate range of capacities from 150 hp up to units producing 200,000 lb of steam per hr or more. The Coxe Stoker is the most widely known of the traveling grate types with more than 2,300 having been installed under boilers with an aggregate heating surface of nearly 10,500,000 sq ft. It is without equal for burning small sizes of anthracite and coke breeze; also is well suited to lignite and some free-burning bituminous coals.

C-E Traveling Grates are forced-draft stokers with the air supply to the entire grate surface under zoned control.

Among *Chain Grate Stokers,* C-E offers types to serve the approximate range of capacities from 150 boiler hp up to units producing 275,000 lb of steam per hr or more. The Green Stoker alone has a record of 4,300 installed under boilers with an aggregate heating surface of over 10,000,000 sq ft. C-E Chain Grate Stokers are particularly well suited to the use of free-burning bituminous coals. They are available in both forced and natural-draft designs.

Whether your conditions of load and the available fuel point to traveling grate, chain grate or any other type of stoker, look to C-E for an installation that can be relied upon to give the best operating and economic results. A-611

Over 16,000 C-E Stokers have been installed to serve 4,500,000 rated boiler hp

COMBUSTION ENGINEERING

200 Madison Avenue New York, New York

C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME THIRTEEN NUMBER TWO

CONTENTS

FOR AUGUST 1941

FEATURE ARTICLES

Huge Power Expansion Planned 20

Transporting the Somerset Steam Drum 22

Combustion Calculations by Graphical Methods *by W. S. Patterson and A. L. Nicolai* 25

Degasification of Steam Samples for Conductivity Tests *by P. B. Place* 31

Notes on Slag Removal 37

Magnetic Test for Cracks in Boiler Tubes 39

Million-Volt Radiography of Boiler Drums 41

EDITORIALS

The F.P.C. Plan for Increased Capacity 19

Ten Years' Advance in Radiography 19

DEPARTMENTS

Book Reviews 42

Equipment Sales—Boiler, Stoker and Pulverized Fuel 43

Advertisers in This Issue 44

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★ Why more and more modern boilers are Flowmatic-controlled

Users of the COPES Flowmatic Regulator will give you many reasons why they are so thoroughly satisfied with this simplified steam-flow type feed water regulator. They will tell of how it has helped get new boilers on the line more quickly, because it gave good feed and level control from the moment it was put into operation. Of how easily it is kept in regular service by no more than routine inspection and care by the plant personnel. Of how closely their boiler water level is held—even on their sharpest load swings—by the two-element COPES Flowmatic.

These are the reasons why more and more modern boilers are being equipped with COPES Flowmatic. These are your reasons for considering COPES Flowmatic for your new boilers. As you can learn from the experience of users in plants like your own, this most-modern feed water regulator gives the results you want—no matter how severe your service requirements. If you would like to check this for yourself, write us for names of installations where you can get first-hand information.

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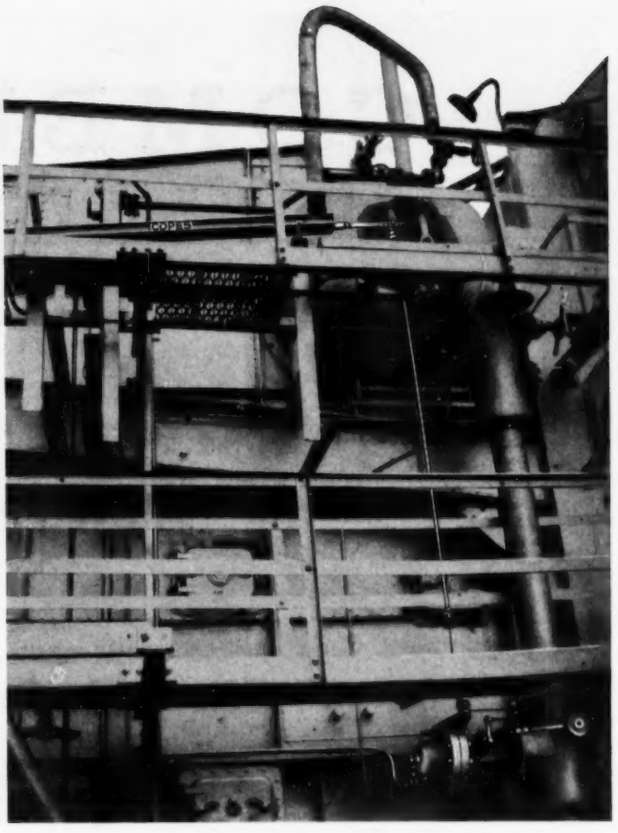
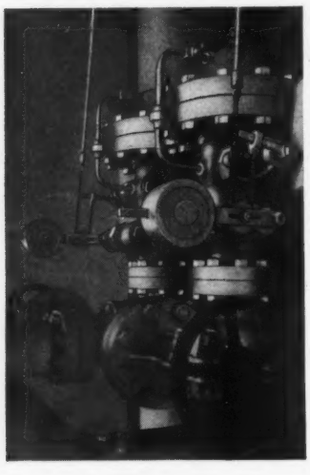
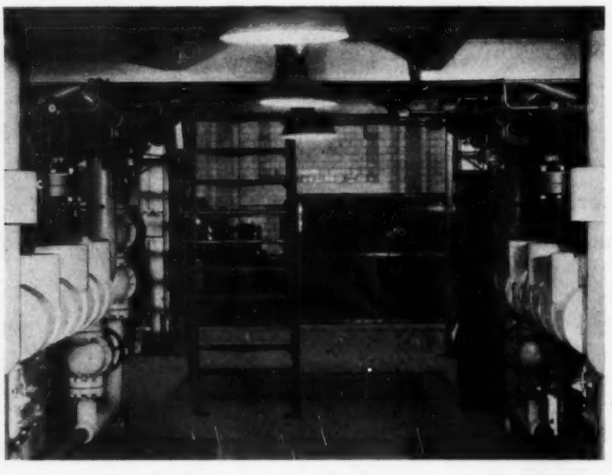


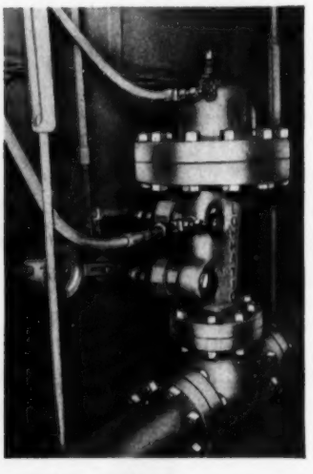
Plant superintendent tells of the excellent results obtained from this all-outdoors COPES Flowmatic Regulator installation on a 450 pound pressure Riley Steam Generator. Write for Bulletin 413.



Master mechanic discusses level control with these Flowmatics on 425-pound Laskers. Bulletin 419.



COPES Flowmatic Regulators on two 650-pound Foster Wheeler boilers in mid-western utility plant. Bulletin 429 gives complete data on Flowmatic design, operation and performance. Write for it.



Bulletin 423 is chief engineer's story of Flowmatic control on 155 pound Vogt textile mill boiler.

★ GET CLOSER LEVEL CONTROL WITH THE COPES FLOWMATIC ★ REGULATOR

FEEDS BOILER ACCORDING TO STEAM FLOW•AUTOMATICALLY

EDITORIAL

The F.P.C. Plan for Increased Capacity

Last spring it appeared to many that present central-station capacity, plus current construction and projected extensions, supplemented by the substantial increases now being made in the industrial power plant field, would be adequate to keep pace with power requirements for defense production in most localities. Where necessary, in some sections it was anticipated that some curtailment in non-essential demands might be found necessary. In fact, there are some who still maintain this view. However, the subsequent and ever-increasing volume of defense orders, which have exceeded all previous estimates, coupled perhaps with the recent power shortage experienced in the South because of drought, has made it expedient for the government to come forward with a plan for further expansion to meet probable demands subsequent to 1942. This was prepared by the Federal Power Commission and is reproduced elsewhere in this issue, with reference to steam capacity.

While these proposals appear to be quite definite, it is understood that they are more or less tentative in that they were based on information available at the time and are subject to change to meet shifting production conditions. Whether all the installations listed will become an actuality depends, of course, on events abroad and the duration of the emergency.

With the present set-up of a power unit in the Office of Production Management, under the direction of J. A. Krug and his advisory committee, working in close cooperation with the Federal Power Commission, it should be possible to maintain almost a running check on requirements and facilities. By means of questionnaires information is constantly being collected on manufacturing facilities to produce power generating equipment and on the progress of new construction. This is being correlated with the power requirements for orders placed in various districts and priorities are issued accordingly. Thus, although the procedure entails a vast amount of work on the part of all concerned it represents a systematic approach to the problem, in lieu of forecasts based on fragmentary information or personal opinions.

There are those who predict that the end of the present emergency will find the utilities with a large amount of excess capacity, in addition to being faced with competition from federal hydro plants in certain localities, for there is certain to be an indeterminate readjustment period during which normal power demands are likely to pick up slowly.

Speaking before the recent E.E.I. Convention in Buffalo, Col. H. S. Bennion advanced the opinion that the major responsibility of the utilities, as a natural monopoly, is to serve domestic and commercial customers, and to a large extent industrial loads, but that they should not be expected to assume responsibility for meeting more than their share of the abnormal defense loads. Thus if a substantial part of the additional capacity needed were to be installed in the plants engaged largely in defense work, the initial expenditure could be written off along with other special equipment when the time for final settlement arrives.

The present emergency has set the stage for further extension of government influence in the conduct of the utility business, which many believe may ultimately approach the relation that has existed for some time in England.

Ten Years' Advance in Radiography

Approval of welding in boiler construction long hinged upon development of an acceptable method of making non-destructive tests of the welds. Radiography provided the answer and it is now just ten years since the A.S.M.E. Boiler Code sanctioned the fusion welding of boiler drums with the provision that they be examined by X-ray. At that time only 200,000 volts was commercially available for such tests and this imposed certain limitations with reference to plate thickness for very high steam pressures and large drum diameters.

X-ray voltages were soon stepped up to 250,000 volts, then to 300,000, and in 1935 to 400,000 volts, thus making it possible to examine welds of plate about five inches in thickness. Satisfactory results were, and are still being, attained with 400,000 volts. However, as the period of exposure increases greatly with plate thickness and as the shorter focal length with this voltage necessitates a large number of exposures, the time involved in radiographing the welds of a high-pressure drum is considerable.

Now, six years later, the million-volt machine has arrived, representing in one jump a boost of 600,000 volts over that previously available. These new machines are capable of radiographing plate up to eight inches in thickness. Not that there are likely to be many drums approaching this thickness, but with four- to five-inch plate, which is common for high-pressure drums, the greater voltage reduces the time of exposure to around one-twenty-fifth of that required with 400,000 volts. This relation increases more rapidly as the plate thickness increases. Also, the greater focal length means fewer exposures and the definition is said to be much sharper.

This means much in reduction in time and labor of testing the welds of a large thick drum, especially at present when so many high-pressure boilers are going through the shops and production schedules are being advanced as much as steel deliveries will permit.

Had it not been for the progress in X-ray development, which permitted boiler manufacturers to take advantage of advances in welding technique, the application of high steam pressures and large units might have been greatly restricted by the necessity of employing the more expensive forged drums.

Huge Power Expansion Planned

A program prepared by the Federal Power Commission contemplates the further addition of approximately 14 million kilowatts of generating capacity over a four-year period beginning in 1943 in order to meet the needs of expanding defense orders. Specific allotments of new capacity to existing plants and to new stations are listed and commitments are to begin immediately. The entire program is estimated to involve an expenditure of between one-and-a-half and two billion dollars.

DESPITE the fact that orders for 6,361,000 kw of new generating capacity were placed between January 1, 1940, and June 30, 1941, defense contracts have expanded at such a rate as to warrant, in the opinion of the Federal Government, a further annual increase in generating capacity of approximately $2^1/_2$ million kilowatts in steam and one million kilowatts in hydro for each year from 1943 through 1946. This added to that already installed, under construction, or on order, should be adequate to meet an estimated defense load by 1943 of around 20 million kilowatts, assuming 11 million kilowatts to represent displacement of normal load. These figures are predicated on the basis that the accelerated defense program will have reached an expenditure of three billion dollars per month by 1943, and the total installed capacity by that time, exclusive of private industrial power plants many of which are being enlarged, will have exceeded 51 million kilowatts.

The plans evolved by the Federal Power Commission, after numerous conferences with the utilities and with the Office of Production Management, cover, for each of the eight regional divisions of the country, the anticipated demand for each year through 1946, the minimum reserves to maintain service, the dependable capacity and the additional capacity required for completion in 1943, 1944, 1945 and 1946. Based on this analysis a detailed schedule of additions to selected stations has been worked out and a number of new plants have also been projected.

It is estimated that the new steam capacity will represent an annual expenditure of between 225 and 300 million dollars, in addition to around 170 million yearly for hydro capacity.

It is anticipated that these orders will keep the electrical equipment manufacturers going at full capacity for the next five years and with the entire program worked out in advance the way will be open to the ordering of materials in accordance with priority schedules that will be established.

The Commission urges further that units be standardized to the maximum possible extent in order to avoid delay in engineering, in shop production and unnecessary overhead.

Chairman Olds of the Federal Power Commission, in his report to the President, suggests that responsibility for the placing and financing of these orders be assumed by the Government through a subsidiary financed by the Reconstruction Finance Corporation, acting upon recommendations of the Federal Power Commission. Utilities, whether publicly or privately owned, should be given an opportunity to undertake the commitments, either directly or on a lease-purchase basis for any units that will be provided for their respective systems. It is further urged that the Commission be authorized to supervise the plans and to make such arrangements for the transfer of generating units to the systems as the situation may require. Immediate financial commitments are contemplated for units to be completed in 1943 and 1944.

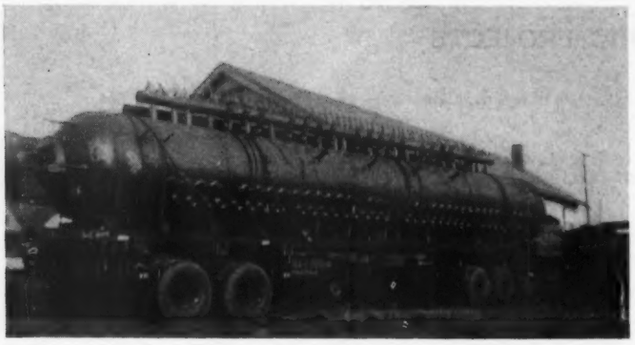
To the U. S. Corps of Engineers, the Bureau of Reclamation and the Tennessee Valley Authority will be delegated the task of constructing a series of river basin projects in accordance with the schedule prepared by the Federal Power Commission on the basis of the regional needs of the defense program.

The report may be considered as a sequel to the President's letter of June 14, 1940, which called upon the Federal Power Commission to coordinate power information and to keep a check on the adequacy of power supply to meet defense needs. Steps will be taken immediately to put the plans into effect to the extent of making available capacity needed in 1943 and 1944. Most of the appropriations that would likely be necessary would fall within existing authorizations for defense.

It is probable, however, that certain modifications as to the units, plants and capacities listed will be found desirable after further consultations with the utilities and as a result of periodic rechecking of defense requirements by the staff of the OPM. But, regardless of such changes as may be necessary, the plan offers a concrete program for insuring adequate power capacity over the emergency period, and forms a basis for the issuing of orderly priorities in the manufacture of generating equipment.

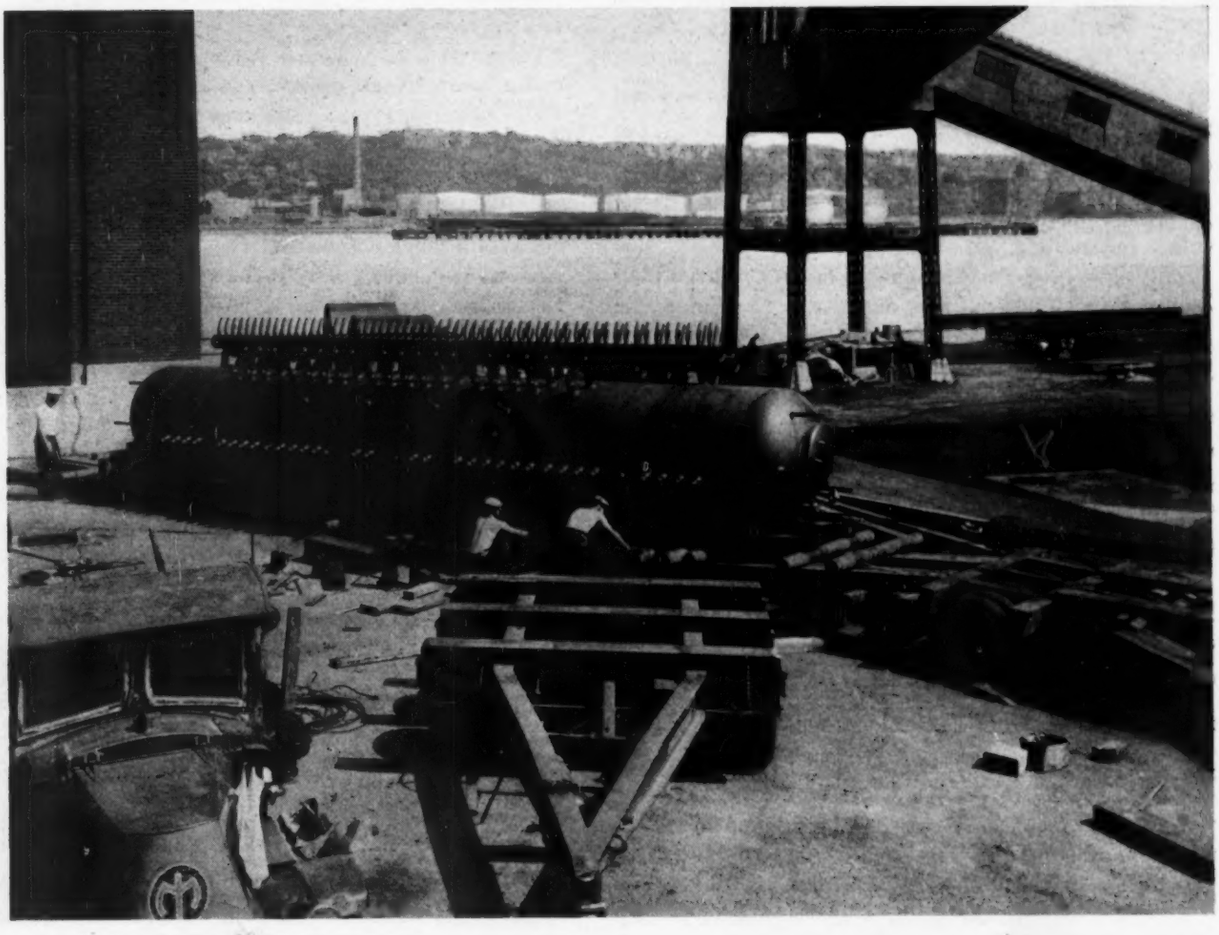
STEAM-ELECTRIC PROJECTS

System	Plant & Location	Capacity to Be Installed, Kw	Year to Be Completed
Region I:			
Central Maine Power Co.	Wiscasset, Wiscasset, Me.	40,000	1945
Boston Edison Co.	Mystic, Boston, Mass.	80,000	1943
		80,000	1944
		80,000	1945
	Edgar, Boston, Mass.	80,000	1945
Narragansett Elec. Co.	Manchester Street, Providence, R. I.	40,000	1945
United Illuminating Co.	English, New Haven, Conn.	80,000	1944
Hartford Elec. Light Co.	S. Meadow, Hartford, Conn.	80,000	1946
Connecticut Light & Power Co.	Montville, Montville, Conn.	40,000	1945
Connecticut Power Co.	Stamford, Stamford, Conn.	80,000	1944
New Hampshire Gas & Elec. Co.	Portsmouth, Portsmouth, N. H.	40,000	1944
Long Island Lighting Co.	Glenwood, New York, N. Y.	80,000	1946
Niagara Hudson Co.	Oswego, Oswego, N. Y.	80,000	1944
		80,000	1946
	Dunkirk (New Plant), Dunkirk, N. Y.	80,000	1943
		80,000	1944
		80,000	1946
	Huntley, Buffalo, N. Y.	80,000	1946
Central Hudson Gas & Elec. Co.	Poughkeepsie, N. Y.	40,000	1945
		80,000	1946
New York State Elec. & Gas Co.	Binghamton, Binghamton, N. Y.	40,000	1946
	Elmira, Elmira, N. Y.	40,000	1946
	Greenidge, Dresden, N. Y.	40,000	1945
New York Power & Light Co.	Schenectady, Schenectady, N. Y.	80,000	1946
Public Service Elec. & Gas Co. of N. J.	Burlington, Burlington, N. J.	100,000	1944
Pennsylvania Power & Light Co.	Stanton, Harding, Pa.	80,000	1945
	Sunbury (New Plant), Sunbury, Pa.	80,000	1944
		80,000	1945
Metropolitan Edison Co.	Middletown, Middletown, Pa.	80,000	1946
New Jersey Power & Light Co.	Gilbert, Holland, N. J.	80,000	1946
Consolidated Gas, Electric Light & Power Company of Baltimore	Riverside, Baltimore, Md.	80,000	1944
		80,000	1945
Potomac Electric Co.	Blue Plains (New Plant), Washington, D. C.	80,000	1943
		80,000	1945
		80,000	1946
Region II:			
American Water Works Co.	Millville (New Plant), Millville, W. Va.	40,000	1944
	Parkersburg, Parkersburg, W. Va.	60,000	1944
	Springdale, Springdale, Pa.	60,000	1943
		60,000	1945
Pennsylvania Electric Co. & Associates	Raystown (New Plant), Raystown, Pa.	40,000	1944
Duquesne Light Company	Philips, Ambridge, Pa.	60,000	1943
		60,000	1944
Cleveland Electric Ill. Co.	Avon, Cleveland, Ohio	100,000	1945
	Lake Shore, Cleveland, Ohio	60,000	1943
		60,000	1944
		60,000	1946
City of Cleveland	Lake Road, Cleveland, Ohio	25,000	1944
Cities Service Power & Light Co.	Acme, Toledo, Ohio	50,000	1944
	Water St., Toledo, Ohio	50,000	1945
	Edgewater, Lorain, Ohio	20,000	1944
		50,000	1946
American Gas & Electric Corp.	Glen Lynn, Glen Lynn, W. Va.	85,000	1943
		85,000	1945
	Philo, Philo, Ohio	85,000	1944
	Parkersburg, Parkersburg, W. Va.	120,000	1945
Public Service Co. of Indiana	Dresser, Dresser, Ind.	60,000	1943
Southern Indiana Gas & Electric Co.	Ohio River, Evansville, Ind.	40,000	1946
Louisville Gas & Elec. Co.	Waterside, Louisville, Ky.	60,000	1946
Kentucky Utilities Co.	Tyrone, Tyrone, Ky.	25,000	1946
Consumers Power Co.	Morrow, Kalamazoo, Mich.	50,000	1945
	Weadock, Bay City, Mich.	50,000	1944
		50,000	1945
Detroit Edison Co.	Trenton Channel, Detroit, Mich.	75,000	1944
		75,000	1946
	Marysville, Marysville, Mich.	75,000	1945
	Conners Creek, Detroit, Mich.	75,000	1944
		75,000	1946
Columbus & S. Ohio Elec. Co.	Picway, Columbus, Ohio	60,000	1944
Cincinnati Gas & Elec. Co.	Columbia, Cincinnati, Ohio	120,000	1944
		60,000	1945
		60,000	1946
Indianapolis Power & Light Company	Harding Street, Indianapolis, Ind.	60,000	1946
Region III:			
Virginia Elec. & Pr. Co.	Petersburg (New), Petersburg, Va.	40,000	1943
		40,000	1946
Virginia Pub. Serv. Co.	Bremo Bluff, Bremo Bluff, Va.	40,000	1943
		40,000	1945
Duke Power Co.	Tiger, Duncan, S. C.	40,000	1943
	Riverbend, Mt. Holly, N. C.	40,000	1943
	Cliffside, Cliffside, N. C.	40,000	1943
	Buck, Spencer, N. C.	80,000	1945
Carolina Power & Light Co.	Cape Fear, Moncure, N. C.	25,000	1943
		25,000	1944
	Raleigh (New) Raleigh, N. C.	50,000	1946
South Carolina Elec. & Gas Co.	Parr Shoals, Parr, S. C.	60,000	1943
		60,000	1945
Alabama Power Co.	Gorgas No. 2, Gorgas, Ala.	60,000	1943
		60,000	1945
	Chickasaw, Mobile, Ala.	40,000	1945
		40,000	1946
	Montgomery (New), Montgomery, Ala.	40,000	1946
Georgia Power Co.	Arkwright, Macon, Ga.	40,000	1943
		40,000	1945
	Columbus (New), Columbus, Ga.	60,000	1944
South Carolina Power Co.	Charleston (New), Charleston, S. C.	25,000	1945
Savannah Elec. & Power Co.	Riverside, Savannah, Ga.	25,000	1944
Florida Power Corp.	River Junction (New), River Junction, Fla.	40,000	1945
Florida Power & Light Co.	Lauderdale, Dania, Fla.	25,000	1946
Region IV:			
Wisconsin - Michigan Power Co.	Green Bay, Green Bay, Wis.	50,000	1945
Wisconsin Electric Power Co.	Port Washington, Port Washington, Wis.	80,000	1944
		80,000	1946
	Commerce Street, Milwaukee, Wis.	50,000	1944
		50,000	1946
Commonwealth Edison Co.	Powerton, Powerton, Ill.	150,000	1944
	Northwest, Chicago, Ill.	80,000	1945
	State Line, Chicago, Ill.	150,000	1944
	Crawford, Chicago, Ill.	80,000	1945
		80,000	1946
Northern Indiana Public Service Co.	East Chicago, East Chicago, Ind.	60,000	1943
	Michigan City, Michigan City, Ind.	80,000	1945
		80,000	1946
Moline-Rock Island Mfg. Co.	Riverside, Iowana, Ia.	50,000	1944
	Moline, Moline, Ill.	50,000	1945
		50,000	1946
Union Electric Co. of Mo.	Ashley Street, St. Louis, Mo.	80,000	1945
		80,000	1946
	Venice, Venice, Ill.	80,000	1944
Northern States Power Co.	High Bridge, St. Paul, Minn.	50,000	1944
Minnesota Power & Light Co.	Duluth, Duluth, Minn.	40,000	1944
		40,000	1946
Des Moines Electric & Power Co.	Des Moines, Des Moines, Ia.	35,000	1944
Interstate Power Co.	Dubuque, Dubuque, Ia.	20,000	1945
Iowa Elec. Light & Power Co.	Cedar Rapids, Cedar Rapids, Ia.	20,000	1945
Kentucky Utilities Co.	Paducah, Paducah, Ky.	40,000	1944
		40,000	1945
Central Illinois Public Service Co.	Grand Tower, Grand Tower, Ill.	40,000	1945
	Meredosia (New Station), Meredosia, Ill.	20,000	1946
Region V:			
U. S. Government	Camden (New), Camden, Ark.	40,000	1943
		40,000	1943
		40,000	1943
U. S. Government	Jonesboro Plant (New), Jonesboro, La.	30,000	1943
		30,000	1943
Gulf States Utilities Co.	Louisiana Plant, Baton Rouge, La.	25,000	1945
Texas-New Mexico Utilities Co.	Tuco Plant, Abernathy, Tex.	20,000	1945
Panhandle Power & Light Co.	Riverview Plant, Berger, Tex.	20,000	1945
San Antonio Public Service Co.	Comal Plant, New Braunfels, Tex.	30,000	1945
Houston Power & Light Co.	Deepwater Plant, Houston, Tex.	30,000	1946
Southwestern Gas & Electric Co.	Arsenal Hill, Shreveport, La.	60,000	1946
Region VI:			
Otter Tail Power Company	Kidder Plant, Wahpeton, N. D.	20,000	1945
Northwestern Public Service Co.	Mitchell Plant, Mitchell, S. D.	20,000	1946
The Kansas Electric Power Co.	Hutchinson Plant, Hutchinson, Kan.	30,000	1946
Empire District Electric Co.	Riverton Plant, Riverton, Kan.	25,000	1946
Region VII:			
Utah Power & Light Co.	Jordan Plant, Salt Lake City, Utah	25,000	1943
		25,000	1944
	Provo Station, Provo, Utah	50,000	1945
The Colorado - Oregon Power Co.	Coos Bay Plant, North Bend, Ore.	30,000	1944
		30,000	1946
Portland General Electric Company	"L" Station, Portland, Ore.	35,000	1945
		35,000	1945
Puget Sound Power & Light Company	Shuffleton Plant, Renton, Wash.	35,000	1945
		35,000	1945
Seattle Municipality	Lake Union Plant, Seattle, Wash.	25,000	1945
Region VIII:			
San Diego Gas & Electric Co.	Silver Gate, San Diego, Cal.	35,000	1944
		35,000	1944
Central Valley Authority	Antioch (New) Antioch, Cal.	75,000	1945
City of Los Angeles, Dept. of Water & Power, Bureau of Power & Light	Harbor Plant, Los Angeles, Cal.	65,000	1945



TRANSPORTING

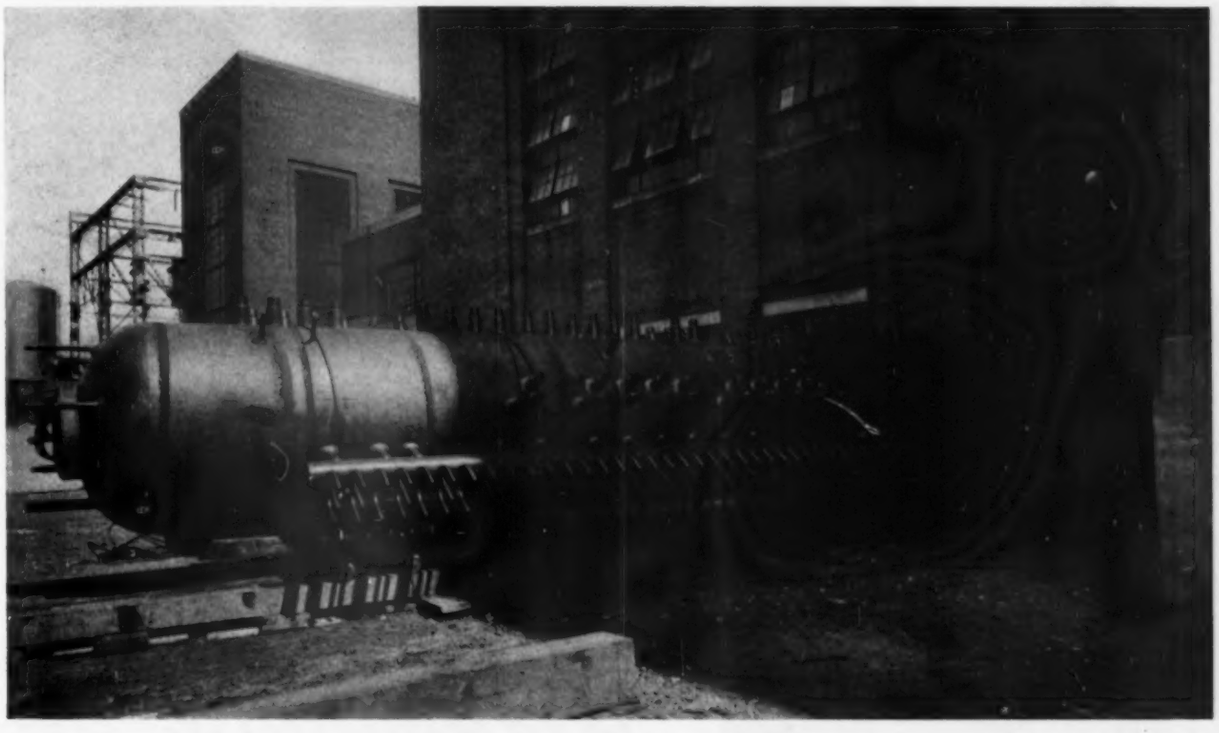
THE accompanying photographs show the main steam drum for the 650,000-lb per hr, 2000-lb pressure C-E controlled forced-circulation unit now being installed at the Somerset Station of the Montaup Electric Company. Shipped by rail from the Chattanooga shops to North Dighton, Mass., it was there transferred to a 32-wheel tractor-drawn double trailer for a 7-mile haul to the plant. All

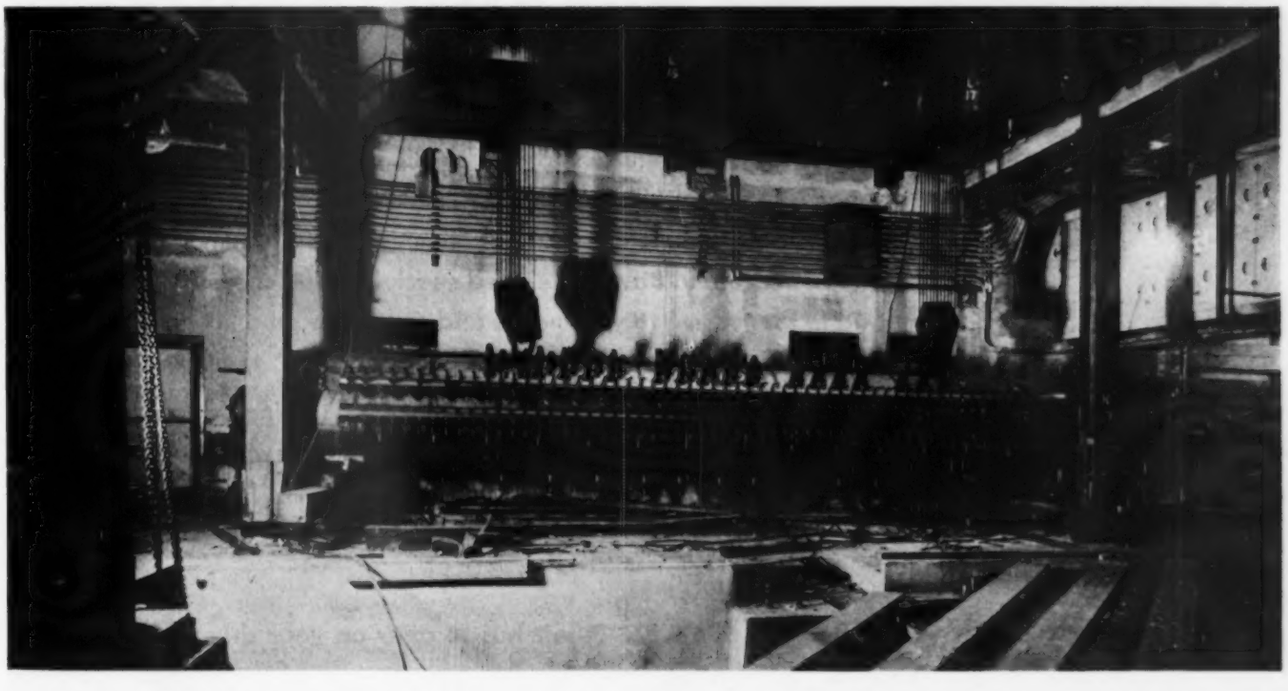


THE SOMERSET STEAM DRUM

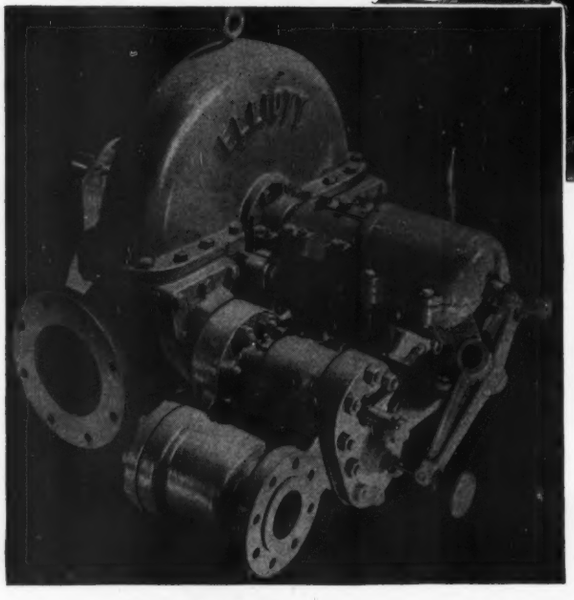
culverts en route first had to be checked carefully because of the unusually heavy load. The drum, which is 43 ft long and 54 in. inside diameter, weighs over 75 tons and because of the large number of welded-on nipples for tube attachment required special care in handling. At one point within the plant there was a clearance of only an inch overall and the drum had to be raised at an angle over girders because of the column spacing. Moreover, this operation had to be accomplished in close proximity to high-tension switching equipment.

Larger and heavier drums than this have been built and shipped by rail or water but the special construction of this drum and the necessity for transferring it from rail to road transport presented a task which was accomplished in less than 1½ days.





For auxiliaries large or small



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H-650

COMBUSTION CALCULATIONS BY GRAPHICAL METHODS

By W. S. PATTERSON and A. L. NICOLAI, Combustion Engineering Company, Inc.

The purpose of the studies of the authors, and of the methods advanced in this article, is to provide charts of the same general character, for all fuels, from which combustion calculations can be made quickly and accurately and without the necessity of having complete ultimate analyses. The chart in the present article deals with fuel oils.

MANY short cut methods of making combustion calculations have been proposed in technical literature. One of these is based on the actual combustion formulas and an assumed or actual fuel analysis, and the graphs drawn simply allow a quick calculation of gas and air weights per pound of a particular fuel with variable excess air. Such a graph is very accurate for the particular fuel analysis used but cannot be extended for use, even with other fuels of the same general character but having different analysis and heat value, without introducing considerable error.

The charts described herein are of the same general type as those offered by Rosencrants,[1] and de Lorenzi and Marshall.[2] In the charts of the first reference, the relationship plotted between CO_2 and excess air is not accurate for the complete range of analyses of some of the fuels mentioned; and the present authors also claim greater accuracy for their charts in calculating products of combustion. The chart of the second reference covered coal only and cannot be improved except to include anthracite and high-oxygen coals; but a more accurate method of making gas weight corrections due to unburned combustible will be presented.

The following are the items discussed in detail with calculation methods for them presented:

1. Fuel in products
2. Atmospheric air
3. Effect of unburned combustible
4. Products of combustion
5. Moisture in air
6. Moisture from fuel
7. Dry gas
8. Carbon dioxide in products

Combustion calculations by the designer are really one of the first steps in the proportioning of a steam boiler. For example: The gas weight resulting from combustion of the fuel is required to determine proper arrangement and extent of heating surface in furnace, boiler, economizer and air heater. The gas weight is also necessary for proportioning gas ducts, dust collectors, induced-draft fans and stacks. The air weight is used to proportion air heater, air ducts, burners and the forced-draft fan.

The first four numbered items are necessary, in the method of the present authors, for the calculation of the gas and air quantities. The items numbered 5 to 7, inclusive, form the basis of heat-balance calculations, either in the design or testing of a steam generating unit, when the A.S.M.E. Test Code, Short Form, is used. The last item, carbon dioxide, and its relationship to excess air is important in combustion calculations because in test work the CO_2 in the gases is measured and from it the excess air is calculated. The equipment designer prefers to work with excess air even though he may appear ostensibly to have based his estimates on the per cent of CO_2.

The charts of the present article are for oil fuel only and are typical of those that will be presented later by Mr. Nicolai to cover natural gas, blast furnace gas, coke oven gas, bagasse, wood and possibly other fuels. These charts will make allowance for all the important variables in the analysis and therefore for practical purposes will be as accurate as if more laborious methods of calculation were used. It should be appreciated that even in working with a complete ultimate analysis and calculating the combustion requirements and products of combustion of each constituent, error of considerable magnitude may result if the heat value used is not correct for the analysis given. Such has been the case in several instances known to the authors.

Basis of Method Employed

Simply stated, the method is based on the conception that the weight of air required in the combustion of a unit weight of any commercial fuel is more nearly proportional to the unit heat value than to the unit weight of that fuel. Consequently, the weights of air, dry gas, moisture, wet gas, etc., are expressed in pounds per million Btu fired. In the case of solid fuels it is difficult to burn 100 per cent of the combustible, so a correction for solid combustible loss must be made.

Before discussing in detail the terms to be found on the charts and in the sample calculations, it is necessary to

[1] COMBUSTION, June 1932.
[2] COMBUSTION, November 1935.

review in a simple way the combustion process of a fuel. Take, for example, a fuel which has no ash; when this fuel burns completely, the weight of the fuel is simply added to the weight of atmospheric air supplied for its combustion to obtain the wet products of combustion or total wet gas. Thus: Fuel (F) + Air (A) = Products (P). But, if some of the fuel is ash, or, if because of incomplete combustion, some of the fuel does not pass out of the furnace with the gases, then F in the above equation will be less and both A and P will also be reduced. This concept of adding F and A to get P is the basis of the method.

"as-fired" heat value of the fuel in Btu per pound. For the other cases where ash and/or solid combustible loss must be considered, equation (1) may be used:

$$F = \frac{10^4(100 - \%\ \text{Ash} - \%\ \text{Solid combustible loss})}{\text{Fuel heat value}} \qquad (1)$$

where:

F = Pounds per million Btu fired
% Ash = Per cent by weight in fuel as fired
% Solid combustible loss = Per cent by weight in fuel as fired
Fuel heat value (HHV) = High heat value as fired, Btu per lb.

Fig. 1 is a plot of equation (1).

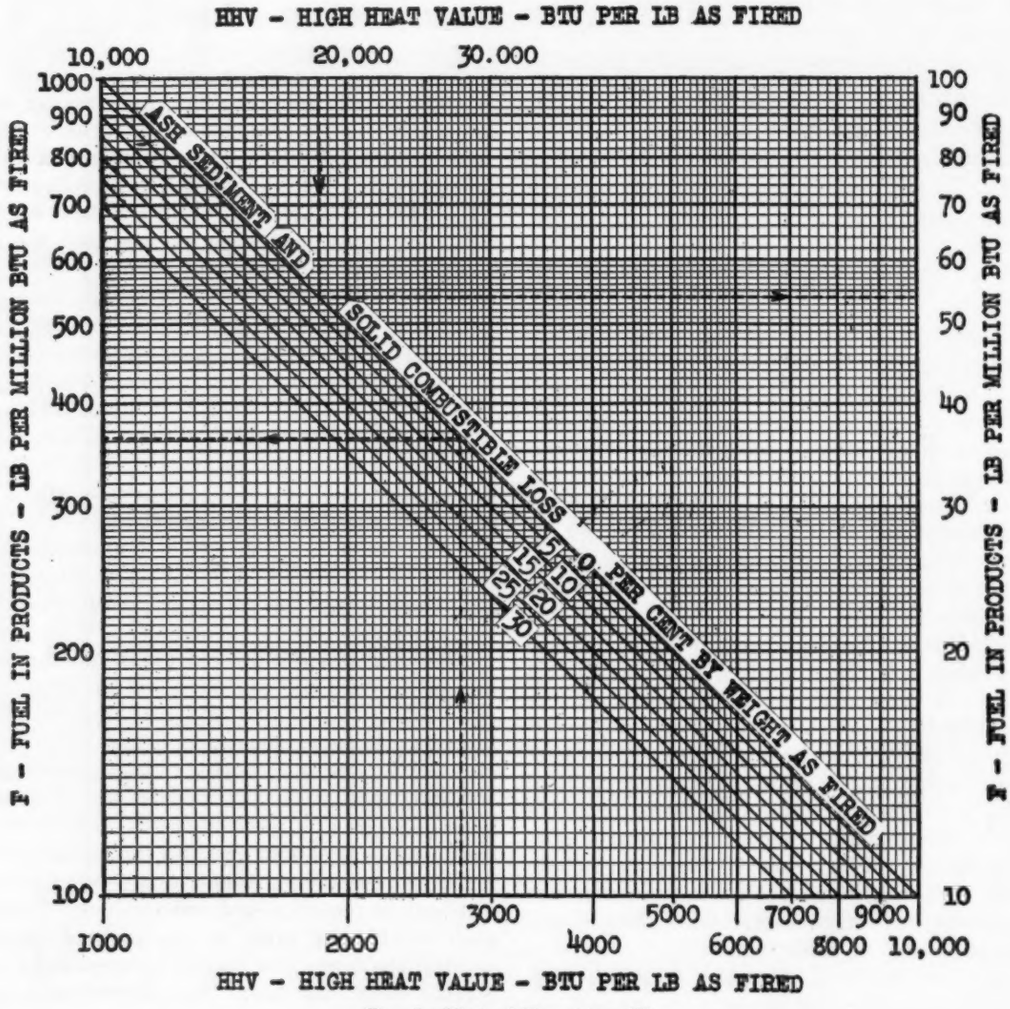

Fig. 1—Plot of Equation (1)

1. *Fuel in Products, F,* is therefore defined as that portion of the fuel fired which, in gaseous form as separate elements or in chemical combination with other elements, reappears after combustion in the gaseous products of combustion. Since with the present method all quantities are to be those required for or resulting from firing 1,000,000 Btu, F must also be calculated on that basis. If a fuel contains no ash and if, in addition, it deposits no carbon in the furnace or on other heating surface, F is simply obtained by dividing 1,000,000 by the

The high heat value is the accepted standard in this country. It is obtained by calorimetric analysis of the fuel in a laboratory. Producers often sell fuel on the basis of its heat value and users generally check it periodically. In any event, manufacturers of steam generating equipment need to know it; and, if it is not furnished, they must make an independent test or calculate it from the constituents. For solid and liquid fuels, empirical formulas must be used, but for gaseous fuels the sum of the heat value of the various combustible con-

stituents may be employed. There may be considerable difference between the analysis "as received" and "as fired," even though nothing is intentionally done to the fuel between the time it is received and the time it is burned. However, certain fuels are purposely dried before they are fired and others take on moisture hygroscopically or are purposely "tempered." In the storage system of pulverized-coal firing, the moisture removed from the coal may actually be vented directly to a stack, but in the direct-fired systems, the moisture, although removed from the coal, is fired with the coal and therefore does not truly alter the combustion quantities.

Likewise, with gaseous fuels, the heat value and analysis are generally reported on the volumetric basis and the temperature and the pressure conditions of the fuel are therefore an essential part of the analysis. Standard conditions are: 62 F and 30 in. Hg.

2. *Atmospheric Air, A.*—All combustion requires oxygen which in commercial practice must be supplied from the atmosphere. The theoretical quantity of oxygen may be calculated accurately from the fuel analysis and simple reaction formulas, such as:

$$C + O_2 = CO_2 \qquad (2)$$

The corresponding weight or volume of dry air required to supply this oxygen may then be calculated, knowing that air contains 23.20 per cent oxygen by weight and 20.96 per cent by volume.

However, natural and manufactured fuels contain varying proportions of several different combustible constituents, such as: C, H_2, S and various hydrocarbons. Some also contain inert constituents, such as: ash, N_2, H_2O, CO_2, as well as oxygen in varying quantities. Obviously, determination of air for combustion then becomes a time-consuming task and shorter methods are usually desirable if accuracy can at the same time be maintained.

Curve *A* in Fig. 2 gives the relation of air quantity to per cent excess air calculated for an average fuel oil, but it may be used for any fuel oil without introducing an error of more than one or two per cent in the air weight. A similar curve for other groups of fuels will be presented in subsequent articles.

It will be noted that Curve *A*, referred to above, is labeled "atmospheric air." This simply means that an arbitrary amount of moisture has been added to the air. The American Boiler Manufacturers Association has agreed to base all proposals on 60 per cent relative humidity at 80 F, which is equivalent to 0.013 lb of water vapor per pound of air. To neglect this would introduce an error of approximately one per cent.

3. *Effect of Unburned Combustible.*—With a well-designed burner and furnace, it is commercially possible to burn so completely all liquid and gaseous fuel that no allowance need be made for loss of combustible in gas and air weight calculations. Therefore, Curve *A* of Fig. 2, which is drawn for oil, is based on complete combustion of the fuel as fired.

In the combustion of solid fuels, even in pulverized form, it is not commercially feasible to burn all the available combustible. As a matter of fact, the relationship between the heat loss due to excess air and the heat loss due to unburned fuel may be such as to make it more economical to operate with a combustible loss considerably higher than the minimum loss which could be obtained.

The method employed to determine the solid combustible loss consists in collecting fly ash and refuse from various hoppers. A dry sample of this collection is then burned in a muffle furnace and its loss of weight due to combustion is measured. This loss of weight can be readily expressed as the per cent by weight of the fuel as fired.

In the combustion of a fuel having pure carbon as the only combustible constituent, the air required may be accurately obtained by multiplying the curve reading (such as Curve *A* of Fig. 2) by the factor

$$C = 1 - \frac{\%\ \text{Solid combustible weight loss}}{100} \qquad (3)$$

because in this case the air for combustion is directly proportional to the carbon in the fuel. If, however, all the heat in the fuel does not come from the carbon alone, so that the air is not strictly proportional to the combustible weight loss, the factor *C* will not be exactly correct. It will be nearly correct for high-carbon, low-volatile fuels and will result in only a small error even for fuels low in fixed carbon and high in hydrogen, because the combustible loss with the latter is generally very small. However, the error involved by using equation (3) in all cases is quite within the limits of accuracy of all other combustion calculations.

For a heat balance the combustible weight loss must be converted to per cent heat loss. This can be done conveniently by dividing the per cent solid combustible weight loss by the heat value of the fuel as fired and multiplying it by 14,600, which is the heat value for combustible in the refuse recommended by the A.S.M.E. Power Test Code for this calculation.

4. *Products of Combustion, P.*—Having calculated the foregoing quantities *F* and *A*, the gaseous products of combustion may readily be determined by the addition of *F* and *A*, as previously corrected. Thus:

$$P = F + CA \qquad (4)$$

where:

- P = Total gaseous products of combustion, pounds per 10^6 Btu fired
- F = Fuel fired exclusive of ash or solid carbon loss, pounds per 10^6 Btu fired
- A = Atmospheric air consumed, pounds per 10^6 Btu fired
- C = Combustible loss correction factor

In references (1) and (2), the authors give a curve for products of combustion, for each fuel or group of fuels, approximately parallel to the air weight curve. This is permissible with reasonable accuracy in restricted cases, but a single line for *P* cannot be used to cover the full range of such fuels as, for example, natural gas. This group has such a wide variation in combustible constituents and heat value that the value of *F* may be different for each analysis. Therefore, greater accuracy in the calculation of gas weight is obtainable by adding *F* and *A* to arrive at *P*, instead of plotting average values of *P* and reading from such a line. However, engineers dealing with specific fuels having only small variations in analysis and heat value may find it convenient to use equation (4) and our curves to plot an accurate curve for *P*, which may be used for calculations.

5. *Moisture in Air, W_a.*—Since the A.S.M.E. Test Code requires that the heat loss due to moisture in air be reported as a separate item in the test heat balance of a steam generating unit, it has become the custom of engineers to include it in a predicted heat balance. In

an actual test, the moisture in air can be determined from wet- and dry-bulb temperature readings, but for a predicted heat balance it must be assumed. It may vary from day to day even in the same locality, but the American Boiler Manufacturers Association has established an arbitrary value for use in preparing proposals. As mentioned above this is taken as 0.013 lb of water per pound of dry air and is included in the atmospheric air A as read from the air-weight curve. When required as a separate item for heat-balance calculations, it will be sufficiently accurate to use an assumed value from the following equation:

$$W_a = 0.013A \quad (5)$$

6. *Moisture from Fuel, W_f.*—This is another item which is separately reported in an A.S.M.E. Test Code heat balance, and likewise in a predicted heat balance. In the case of some fuels, such as natural and refinery gases, the heat loss due to this moisture may be the largest single item in the heat balance. W_f includes the combined surface and inherent moisture, W_c, from a fuel plus the moisture formed by the combustion of hydrogen, W_h. The former will vary from zero or a mere trace in fuel oil to over 115 lb per million Btu fired in the case of green wood; the latter will vary from zero or a trace in lampblack to 100 lb per million Btu fired in the case of some refinery gases.

Special charts, or groups of curves, will be drawn for calculating W_f on each fuel. For the oil fuels specifically covered by this article, curve group C may be used, where W_f is merely the moisture from hydrogen, and W_h, is determined from the following equation:

$$W_h = 9 \times H_2 \times \left(\frac{10^4}{HHV}\right) \quad (6)$$

where:

W_h = Moisture from combustion of H_2, pounds per million Btu fired
H_2 = Hydrogen in fuel, per cent by weight
HHV = High (gross) heat value of fuel, Btu per lb

7. *Dry Gas, P_d.*—The necessity of calculating the dry gas or dry products as contrasted with, and in addition to, the total products, is due to the A.S.M.E. Test Code. Dry gas loss is a separate item of the heat balance.

The dry gas may be determined by subtracting the water vapor from the total products, thus:

$$P_d = P - (W_a + W_f) \quad (7)$$

where:

P_d = Dry gas, pounds per million Btu fired
P = Total products of combustion (Item 4)
W_a = Moisture in air (Item 5)
W_f = Moisture from fuel (Item 6)

8. *Carbon Dioxide in Products, CO_2.*—The CO_2 in the gases leaving a furnace or boiler is used by the operators as a guide in adjusting the air supplied, so as not to use too much excess air and in this way decrease the efficiency. Conversely, however, if the CO_2 is maintained too high so that the excess air is too low, there will be incomplete combustion of volatile fuel and a higher than normal loss in unburned fixed carbon.

The Orsat apparatus and all other chemical, mechanical or electrical means for analyzing flue gas, measure the constituents of the gases and not the excess air. However, it is desirable that the excess air be known because in many calculations the direct use of excess air rather than CO_2 greatly simplifies the work.

Relation between CO_2 and Excess Air

It is, therefore, quite necessary that the relationship between CO_2 and excess air for all fuels be known. It has been shown in the references (1) and (2) that for bituminous coals, this relationship may be quite accurately expressed in graphical form by means of two curves, one for high-volatile and one for low-volatile fuel. However, there is greater variation in the ratio of carbon to hydrogen in other fuels, such as oil and gas, and a whole family such as curves B of Fig. 2 may be required to cover the full range of analyses. The wide variation in excess air for a given CO_2 as illustrated by these curves proves that it is not wise to think of CO_2 as synonomous with excess air except when dealing with one particular fuel analysis for which the CO_2-versus-excess air relationship is known.

The relationship between CO_2 and excess air for a fuel of known analysis can be calculated by methods which are familiar to most engineers and may be found in almost any textbook having a chapter on combustion. Some engineers prefer to make calculations on a weight basis even for gaseous fuels while others prefer the volume or mol system for all fuels and, for the same reason, most textbooks give only one or the other method. The use of the volumetric method was covered in considerable detail by De Baufre.[3]

As in the case of bituminous coal, it will be found from a study of the calculated CO_2 vs. excess air relationship that a family of curves can be drawn to cover the whole range of analyses of fuels in a given group, as, for example, Curve B of Fig. 2.

In the foregoing general discussion, the curves prepared for fuel oils have been used for the purpose of illustrating the method. These curves together with the following section are typical of what will be presented in subsequent articles of this series to cover other individual groups of fuels. The general discussion and Fig. 1, however, will apply to the whole series.

The tables and typical example have been placed on the reverse side of the chart (see page 30) so as to provide a convenient arrangement should the reader desire to clip and file the chart without including the whole article. A similar arrangement will be provided with the subsequent charts covering natural gas, blast-furnace gas, coke-oven gas, bagasse, wood and other fuels—EDITOR.

[3] COMBUSTION, August 1931.

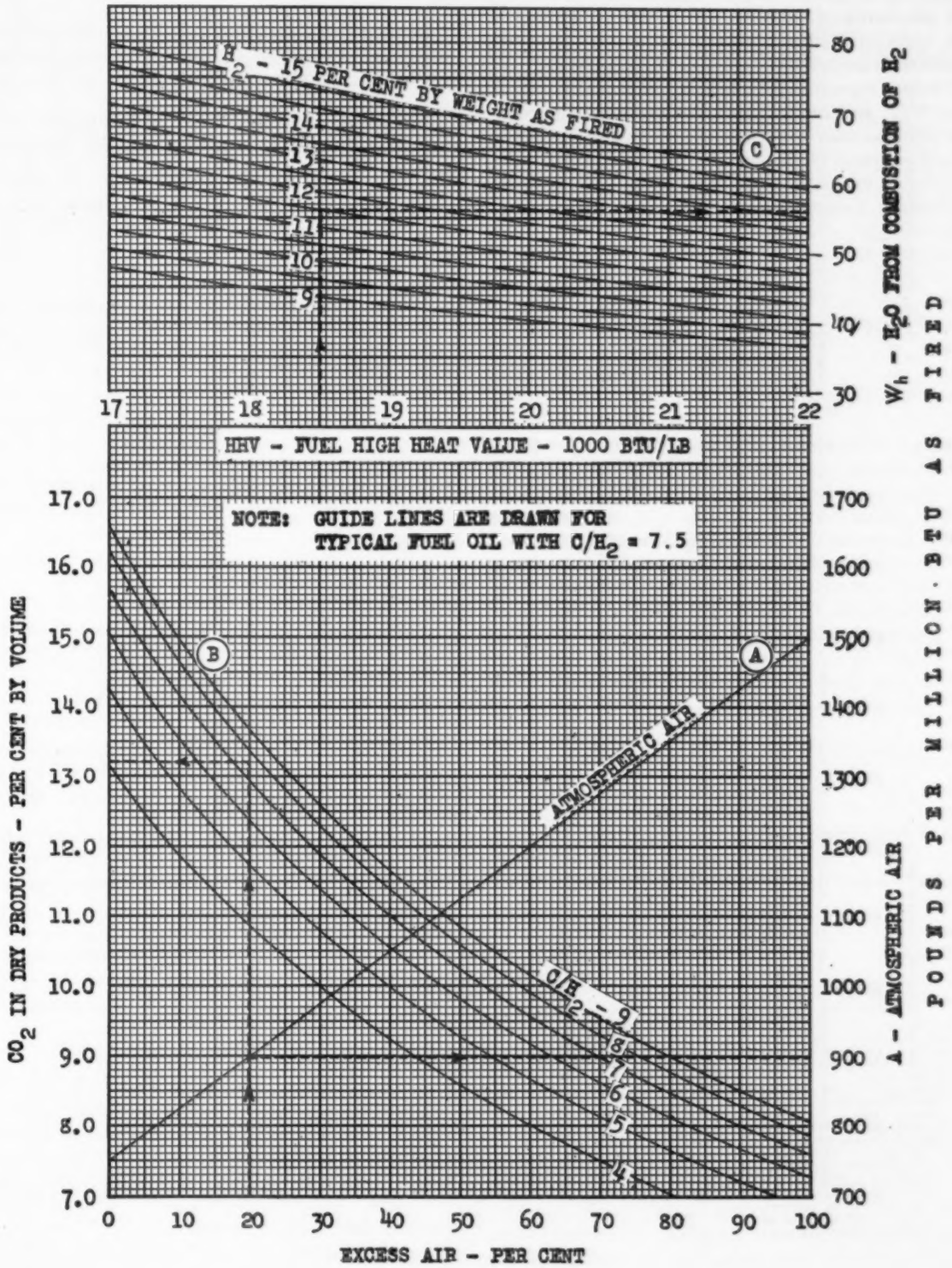

Fig. 2—Chart for Fuel Oil

Fuel Oils

(See chart on reverse page)

The oils ordinarily burned are derivatives of petroleum, comprising the so-called "Bunker" grades, diesel-engine oils, gas oils, kerosene, gasoline, etc. As they all have a common source, the constituents of their analyses are the same, although the relative quantity of each varies. W. L. De Baufre's representative tabulation in his article on "Typical Solid and Liquid Fuels"[3] shows that the combustible fraction chiefly consists of carbon and hydrogen with small amounts of sulphur. Negligible percentages of nitrogen and oxygen as well as water and sediment are also frequently found. De Baufre's table is, in part, reproduced below:

TABLE 1. CHARACTERISTICS OF TYPICAL SOLID AND LIQUID FUELS

	°API	% C	% H_2	% S	% N_2	% O_2	HEAT VALUE BTU/LB High	HEAT VALUE BTU/LB Low	ATMOSPHERIC AIR Lb/10^6 Btu	CO_2 AT ZERO Excess Air
Gasoline	60	85.0	14.8	...	0.1	0.1	20,200	18,762	746	14.87
Kerosene	45	85.0	14.0	...	0.5	0.5	19,900	18,540	742	15.12
Gas oil	30	85.0	12.8	0.8	0.7	0.7	19,300	18,056	745	15.48
Fuel oil	15	85.5	11.5	1.6	0.7	0.7	18,500	17,383	758	15.90

The atmospheric air, A, in pounds per million Btu as fired and the per cent CO_2 in the products, both for zero excess air, are also tabulated for the different oils.

For commercial furnaces, Bunker *C* oil is frequently specified. As commonly understood, the term "Bunker *C*" has come to be applied to the heavier fuel oils having a viscosity from 100 to 300 S.S.F. at 122 F. Bunker *C* oil roughly corresponds to No. 6 fuel oil in the following table, "Commercial Standard for Fuel Oils" by the Bureau of Standards.

Oils are often graded in terms of specific gravity according to the following relations:

$$\text{Degrees API} = \frac{141.5}{\text{Sp. gr., } 60/60\text{ F}} - 131.5$$

and

$$\text{Degrees Baumé} = \frac{140}{\text{Sp. gr., } 60/60\text{ F}} - 130$$

If the Baumé gravity is known, the following formulas, adapted from the original Sherman and Kropff formula, may be used to find the high heat values

Fuel oil—18,250 + 40 (deg. Bé. − 10) Btu per lb
Kerosene—18,440 + 40 (deg. Bé. − 10) Btu per lb
Gasoline—18,320 + 40 (deg. Bé. − 10) Btu per lb

If the specific gravity, (d), at 60 F is known, the U. S. Bureau of Standards[4] recommends for all petroleum products:

Heat of combustion at constant volume = 22,320 − $3780d^2$ Btu per lb

Example

Assume a fuel oil, with the typical analysis given in De Baufre's table, to be burned with 20 per cent excess air. Then,

1. Fuel F. From Fig. 1 for a high heat value of 18,500 Btu per lb and 0 per cent ash read F = 54 lb per million Btu.
2. Atmospheric Air, A. From Curve A, Fig. 2, read A = 900 lb per million Btu.
3. Unburned Combustible. In the combustion of fuel oils, in stationary boiler furnaces, it is generally assumed that there is no combustible heat loss. Therefore C in equation (3) is equal to 1.
4. Total Products, P. From equation (4), $P = CA + F = 1 \times 900 + 54 = 954$ lb per million Btu.
5. Moisture in Air, W_a. From equation (5), $W_a = 0.013\ (A) = 0.013\ (900) = 12$ lb per million Btu.
6. Moisture from Fuel, W_f. Since $W_a = 0$, from Curves C, Fig. 2, for a high heat value of 18,500 Btu/lb and H_2 of 11.5 per cent read $W_f = W_h = 56$ lb per million Btu.
7. Dry Gas, P_d. From equation (7), $P_d = P - (W_a + W_f) = 954 - (12 + 56) = 886$ lb per million Btu.
8. Per Cent CO_2 in Products. From Curves B, Fig. 2, for 20 per cent excess air and a C/H_2 ratio of 7.5 read CO_2 = 13.2 per cent.

[4] Misc. Pub. No. 97, " Thermal Properties of Petroleum Products," 1929.

TABLES 2. COMMERCIAL STANDARD FOR FUEL OILS, U. S. BUREAU OF STANDARDS

No.	Grade Description	Flash Point, °F. Min.	Flash Point, °F. Max.	Pour Point °F. Max.	Water and Sediment (%) Max.	Carbon Residue (%) Max.	Ash (%) Max.	VISCOSITY (Seconds) Saybolt Universal (at 100°F.) Max.	VISCOSITY (Seconds) Saybolt Universal (at 100°F.) Min.	VISCOSITY (Seconds) Saybolt Furol (at 122°F.) Max.	VISCOSITY (Seconds) Saybolt Furol (at 122°F.) Min.
1	A distillate oil for use in burners requiring a volatile fuel	100 or legal	150	15	0.05	0.02	...	...	..	...	...
2	A distillate oil for use in burners requiring a moderately volatile fuel	110 or legal	190	15	0.05	0.05	...	...	..	...	...
3	A distillate oil for use in burners requiring a low-viscosity fuel	110 or legal	200	15	0.1	0.15	...	70	..	...	...
4	An oil for use in burners requiring low-viscosity fuel	150	...	..	1.0	....	0.1	500	70	...	...
5	An oil for use in burners equipped with pre-heaters permitting a medium-viscosity fuel	150	...	..	1.0	....	0.15	...	..	100	25
6	An oil for use in burners equipped with pre-heaters permitting a high-viscosity fuel	150	...	..	2.0	....	...	...	..	300	100

DEGASIFICATION of STEAM SAMPLES for CONDUCTIVITY TESTS*

By P. B. Place

Combustion Engineering Company, Inc.

A summary of the methods and apparatus available for the elimination from steam samples of gaseous impurities that affect conductivity measurements. The principles involved in the various methods are briefly discussed and the apparatus as developed by various investigators is described. In their present state of development, continuous flow degasifiers will reduce carbon dioxide to an amount that constitutes a negligible conductivity error for commercial testing. Ammonia, being more soluble and having a very high conductivity, is much more difficult to reduce to negligible amounts, and it is usually necessary to make conductivity corrections for the residual ammonia left in the degassed sample.

ONE of the problems in the development of the conductivity method for testing steam purity has been the correction for, or elimination of, acid and basic gases in the steam which yield ionized compounds in solution that contribute to the conductivity of the sample but which yield no solid residue on evaporation. Although such gases as CO_2, NH_3, H_2S and SO_2 constitute an impurity in the steam, they are not classified as such in a commercial sense because they yield no solid residue that will deposit in superheater tubes or on turbine blades.

There are obviously two methods of approach to this problem. The amount of gaseous impurity in the sample may be determined and a suitable correction applied to the conductivity of the sample, or the gaseous impurity may be eliminated from the sample before the conductivity of the latter is measured.

The determination of a suitable correction for the gaseous impurities is difficult, although much progress has been made in this direction. Not only is the conductivity of some of these gases much greater than the conductivity of the neutral salts normally present in the steam, but the amount of gases may vary considerably because the gas carryover from the boiler is not a function of the moisture carryover but rather a function of the rate of gas liberation in the boiler.

In view of these difficulties, it would appear to be easier and more desirable to eliminate the gases from the sample before the conductivity tests are made and thus avoid making any corrections.

Theory

Gases are held in solution in condensed steam in two ways. They may be in simple solution by virtue of their partial pressure, or they may combine in solution to form ionized compounds. When in simple solution they are relatively easy to eliminate and do not form ionized compounds that affect conductivity tests. Acid and basic gases combine with water or with each other to form ionized compounds that do affect conductivity and such gases are more difficult to remove than those in simple solution.

The elimination of gases from simple solution is the reverse of absorption, which follows Henry's law. This law states that at any constant temperature, the weight of gas dissolved by a definite volume of liquid is proportional to the partial pressure of the gas above the liquid. The greater the partial pressure imposed on the liquid, the more gas there is in solution when equilibrium conditions are established. Conversely, the lower the partial pressure of gas above the liquid, the less gas there is in solution under equilibrium conditions.

All methods of degasification are primarily aimed at reduction of partial pressure. In degasification, the gas is liberated from the liquid to approach the partial pressure corresponding to the equilibrium conditions. For complete elimination of the gas, it is necessary to destroy continuously this equilibrium by continuously removing the liberated gas from the space above the liquid and to allow time for the residual gas to liberate itself under conditions of a constantly decreasing differential partial pressure.

As in all reversible reactions governed by the law of mass action, the rate at which equilibrium is re-established by further liberation of gas will decrease as the concentration of dissolved gas decreases. It will also decrease as the differential partial pressure between gas in solution and liberated gas decreases. It is evident that for complete elimination of gases from solution, not only must the liberated gas be completely removed from the space above the liquid, but time must be allowed for the liberation of residual gas under constantly decreasing, low-differential, partial-pressure conditions.

A resistance to the rate of elimination is the rate of diffusion through the liquid and through the gas films at the surface of the liquid. The rate of diffusion through the interface is a controlling factor in the elimination of gases from liquids in the quiescent state. Boiling, bubbling inert gas through the liquid, shaking

* A paper presented at a Symposium on Determination of Steam Purity during the Annual meeting of the American Society for Testing Materials at Chicago, June 23–27, 1941.

or otherwise disturbing the interface films contributes greatly to speeding up the rate of transfer in an unbalanced equilibrium and degasification may be materially hastened by increasing the temperature of the solvent, by reduction in the total pressure above the liquid or by use of scavenging carriers such as steam or an inert gas which sweeps the liberated gas out of the liquid and away from the space above the liquid.

The usual undesirable gases found in steam are CO_2 and NH_3. Gases other than these are seldom found and

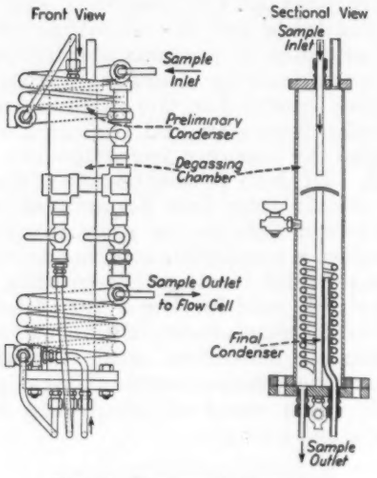

Fig. 1—Rummel degasifier

this discussion will be limited to these two. These two gases, in solution, unite with water or with each other to form one or more unstable salts. An equilibrium is set up between the amount of gas above the liquid, the amount in simple solution and the amount in chemical combination. The distribution of the gas in this equilibrium depends on temperature, concentration, pH value and other factors. McKinney (1) and Amorosi and McDermet (2) have discussed this equilibrium and described methods for calculation of the distribution in dilute solution.

Here again, degasification depends largely on reduction in partial pressure. Reduction or elimination of the gas in simple solution shifts the unstable equilibrium to the left and results in reduction of the ionized portion of the gas. Although such factors as temperature and partial pressure can be controlled to favor the elimination of the gas in simple solution and reduction in the ionized portion, the pH value of the sample cannot be controlled by the addition of chemicals without making the sample useless for steam purity tests. Elimination therefore depends not only on the continuous removal of gas above the liquid, but also on maintenance of conditions of temperature, surface, scavenging and time to favor the shift in distribution of gas from ionized form to simple solution.

It is generally accepted that CO_2 may be easily reduced to an amount that does not constitute an appreciable conductivity error in steam purity tests, but that NH_3 is much more difficult to reduce to a similarly negligible amount. The reason for this is probably threefold. First, CO_2 is less soluble than NH_3 and for the same concentration it has a proportionately larger partial pressure to work on. Second, the conductivity of NH_3 is about ten times that of CO_2 and it is necessary to reduce the NH_3 concentration to a much lower value to give a similar conductivity error. Third, CO_2 cannot be detected in small amounts with the same accuracy as NH_3 and it is relatively easy to obtain negative tests that indicate complete elimination of this gas. If tests for CO_2 were as accurate as for NH_3, conclusions as to the relative ease of complete elimination of these two gases might be different.

There may be some question as to whether a very soluble and high conductivity gas such as NH_3 can be sufficiently eliminated in continuous flow degasifiers or by simple distillation to reduce its conductivity error to a negligible value. The elimination of an acid gas such as CO_2 is favored by a low pH value and the elimination of a basic gas such as NH_3 is favored by a high pH value. Small amounts of carryover from an alkaline boiler water should favor rather than inhibit elimination of NH_3 and there appears to be no good reason why complete elimination cannot be obtained if the various conditions of temperature, time, scavenging, and surface are suitably controlled.

Classification of Methods of Degasification

The various methods in use for the elimination of gaseous impurities in steam samples may be classified as follows:

1. Continuous sample methods:
   - (*a*) Elimination by boiling.
   - (*b*) Elimination by evacuation.
   - (*c*) Elimination by aeration.
2. Batch sample methods:
   - (*a*) Elimination by distillation.

In the continuous methods, a continuous flow of sample is maintained through the degasifier, in which a complete and continuous elimination of gas is attempted. The degasifier is followed by a conductivity flow-type cell for measurement of the conductivity of the degassed sample.

In batch methods, steam condensate samples are collected and tested individually. Distillation in some form is the basic process in these methods and the time required for such tests is so long that only occasional results can be obtained. The value of batch method tests is chiefly in checking continuous flow conductivity records and in checking composite samples collected over a period of time. When the amount of gas in the steam is low and fairly constant, the conductivity of the steam may be determined continuously without degasification and the correction for the gases determined occasionally by a batch method test. Similarly, if the continuous flow degasifier does not give complete elimination of the gases, the residual gas in the sample may be determined by occasional batch tests and suitable corrections applied to the continuous conductivity record of the partially degassed sample.

Application of Continuous Elimination by Boiling.—Soon after the conductivity method had been applied to steam condensate testing, Rummel (3) developed a continuous flow degasifier. The apparatus, modified somewhat from the original design, is shown in Fig. 1. The steam sample is first partially condensed in the external cooling coil located at the top of the apparatus. The

hot mixture of steam and condensate is then admitted to the degassing chamber in which is located a second cooling coil and to which is attached a vent. By careful control of the flow of cooling water to the preliminary and final condensers, the condensate which collects in the degassing chamber is maintained at the boiling point and the liberated gases, together with some scavenging steam, are vented to the atmosphere. The gas-free condensate is drawn off continuously from the bottom of the chamber, cooled in an outside cooling coil, and its conductivity measured in a flow-type cell.

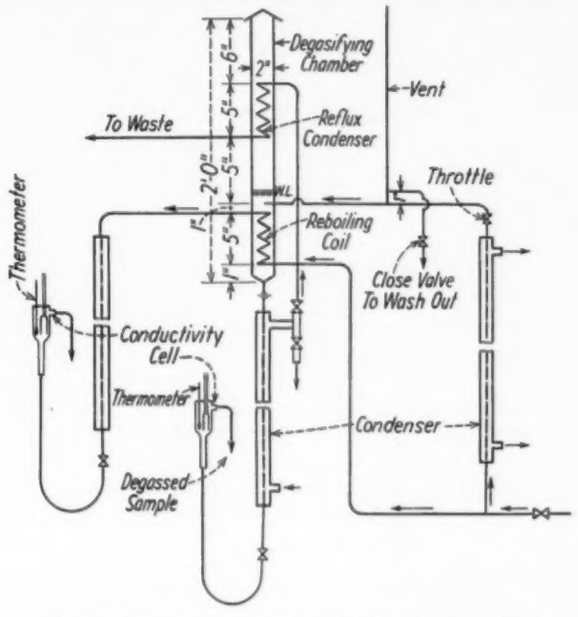

Fig. 2—Gurney, Schwartz and Crossan degasifier

A somewhat different design of degasifier of the boiling type was developed by Gurney, Schwartz and Crossan (4) and is shown in Fig. 2. In this apparatus the condensed steam delivered to the degassing chamber is reboiled by a steam-heated coil submerged in the condensate. A reflux condenser located in the upper part of the chamber prevents excessive loss of steam vapor but allows venting of the liberated gases. By controlling the steam flow to the reboiling coil and the cooling water supply to the reflux condenser, the condensate in the chamber is kept at the boiling point and the liberated gases escape through the vent. The steam used in the reboiling coil is part of the steam sample and the conductivity of the condensate from this coil may be determined to give data on the undegassed steam.

This apparatus will eliminate all but a negligible amount of CO_2 and reduce the NH_3 concentration, but residual NH_3 should be determined separately and suitable corrections applied to the continuous conductivity record. A typical residual of 0.14 ppm of nitrogen in the form of ammonia is reported by Gurney as having a conductivity correction of 1.12 micromhos.

Straub and Nelson (5) recently reported the development of the continuous degasifier shown in Fig. 3. This apparatus is described as making use of the principle of boiling a sample of condensed steam from which the gases have been removed, to furnish gas-free steam, which in turn is used to scrub the gases from the incoming sample. The principle feature of this apparatus is the use of a scrubbing tower or stripping column imposed over the boiling chamber. This tower contains a large amount of surface in the form of perforated plates over which the condensed steam sample flows in a thin film while being degassed. A reflux condenser located above the stripping column prevents excessive loss of steam but permits venting of the liberated gases and a small amount of scavenging steam. The steam sample is first admitted under pressure to the reboiling coil located in the bottom of the degassing chamber, where it is partially condensed in reboiling the collected condensate. The partially condensed sample is next completely condensed and cooled in the upper external cooling coil. Part of this condensate is passed through a flow cell for determination of the conductivity of the undegassed sample and a controlled portion of the remainder is admitted to the degassing chamber through an orifice and preheating coil. The preheated sample is distributed and trickled down over the perforated plates and is degassed by the steam rising from the boiling condensate in the bottom of the chamber. With this apparatus, under controlled conditions of flow, complete elimination of both CO_2 and NH_3 is claimed.

Fig. 4 shows a somewhat similar apparatus developed by the Elliott Company (6). It utilizes the scrubbing tower principle, the incoming sample being distributed and trickled over a series of plates located in the steam space above the boiling degassed sample. An unusual feature of this equipment is the use of electric heating elements for boiling the condensate. Although primarily designed for removal and collection of gases in steam condensate, the apparatus is suitable for degasification of steam samples for conductivity tests, provided the electric heating elements do not introduce undesirable contamination. An advantage of the electric heating system is its adaptability to automatic control for maintenance of the proper operating conditions. The sample drawn off for conductivity test is cooled to a suitable temperature in an outside cooling coil not shown in the diagram.

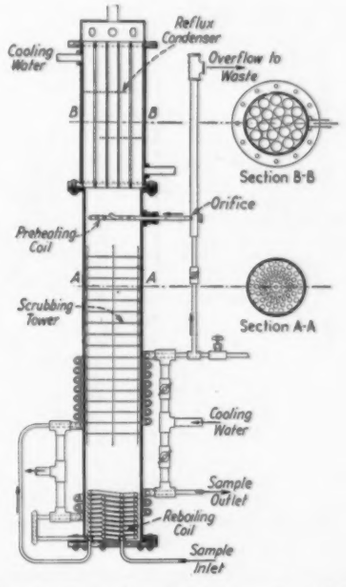

Fig. 3—Straub and Nelson degasifier

The degasifier shown in Fig. 5 is classified as of the boiling type, but has the additional feature of atomization. Although designed primarily for the separation and collection of hydrogen and other gases from steam, it is applicable to degasification of the steam samples for conductivity tests and has been described by Joos (7). The apparatus consists of two chambers, one of which is the condensing chamber and the other is the atomizing chamber. Steam is admitted under pressure through an orifice located in the bottom of the atomizing chamber. The condensate which collects in the bottom of this chamber is atomized and boiled by the incoming steam and the steam vapor and liberated gases are swept over into the condensing chamber in which the steam is recondensed and from which the gases are vented. The condensed steam is recirculated to the atomizing chamber and the atomization continuously repeated. The hot, degassed condensate is drawn off from the bottom of the atomizing chamber and cooled in an outside cooling coil before passing through a flow-type cell for conductivity measurement. No data on removal of CO_2 and NH_3 are available, but the repetition of the atomizing cycle favors efficient elimination of these gases.

Application of Continuous Elimination by Evacuation.—Attacking the problem of degasification from a different angle, Powell (8), and Powell, Bacon, McChesney and Henry (9) developed the apparatus shown in Fig. 6. In this apparatus the steam sample is condensed under reduced pressure and discharged into a flow-type cell which is evacuated to a pressure approaching the vapor

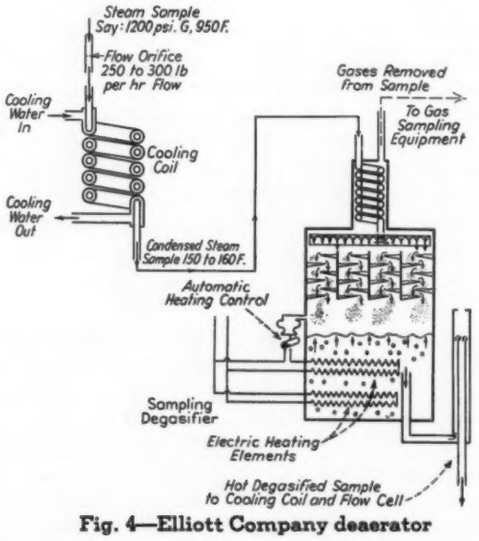

Fig. 4—Elliott Company deaerator

pressure of water at the sample temperature. The high vacuum, aided by the scavenging effect of small amounts of water vapor drawn off through the evacuating element, maintains a practically gas-free atmosphere in the system. The temperature in the evacuated flow cell is normally below 80 F and suitable for direct conductivity measurement without further cooling. The overflow from the cell is through a barometric water leg which serves as a seal. With this apparatus large amounts of CO_2 have been reduced continuously to negligible residuals. Ammonia is reduced but complete elimination is not claimed. Residual NH_3 is determined and suitable corrections applied to the continuous conductivity record.

Application of Continuous Elimination by Aeration.—An example of aeration applied to a continuous flow method of degasification is described by Powell, Bacon, McChesney and Henry (9). In this apparatus the condensed steam is atomized under pressure by a small spray nozzle and the resulting mist is aerated by an induced current of clean air. The mist is condensed on the walls of the aeration chamber and collects in a flow cell in which its conductivity is measured. The air,

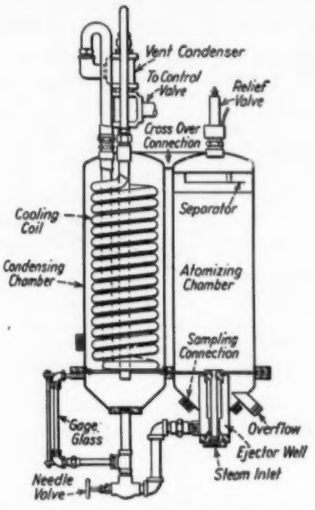

Fig. 5—Joos atomizing degasifier

together with the liberated gases, escapes through a vent. This method is effective in reducing large and variable amounts of CO_2 to small and fairly constant amounts for which suitable corrections can be applied. No data are available on elimination of NH_3.

Application of Batch Elimination by Distillation.—Practically all batch methods involve boiling and distillation, although aeration and evacuation are as applicable to batch methods as to continuous methods. In some cases, a considerable portion of the sample is boiled away with the liberated gases and the non-volatile impurities determined in the concentrated residue. In other cases the object of the test is to distill off and collect the liberated gases to determine a suitable correction for conductivity data. Since methods involving the determination of gas corrections are dealt with in another paper (10), the only method discussed here will be one in which the primary object is the determination of the non-volatile impurities in the concentrated residue after the volatile impurities have been distilled off.

The author has described such a distillation method (11), using the apparatus shown in Fig. 7. A 1- to 2-liter sample is distilled and the progress of gas evolution noted by conductivity and titration tests on the distillate. When these tests indicate no further evolution of gas, the conductivity and volume of the cooled residue in the still are measured and the purity of the original sample calculated by proportion.

A typical distillation test is shown in Fig. 8. A 2300-ml sample containing 8.5 ppm of CO_2 and having a conductivity of 5.5 micromhos, is concentrated by distillation to a 300-ml residue having a conductivity of 2.9 micromhos. The large rectangle and cross-hatched square

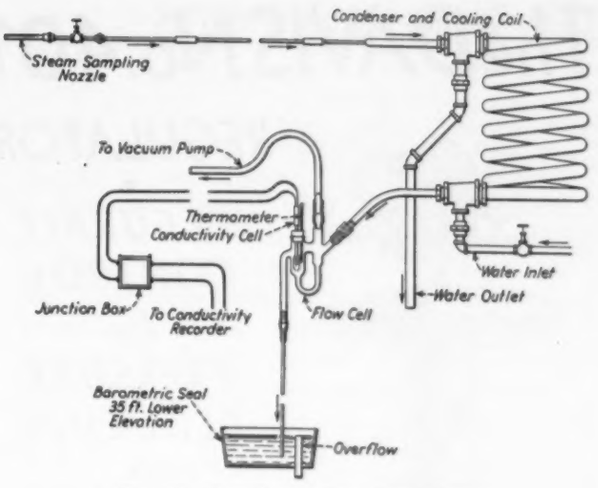

Fig. 6—Powell vacuum degasifier

at the bottom of Fig. 8 represent, respectively, the conductivity of the sample and the proportion of that conductivity due to non-volatile impurities.

Since the slope of the conductivity curve at the end of the distillation indicates that gases are still being eliminated, the curve may be extrapolated to complete distillation and the double-hatched area subtracted as a correction. Although such correction may be questioned, it serves to counteract high results due to residual NH_3 or contamination. In this case, the corrected steam conductivity would be

$$\frac{300 \times (2.9 - 0.8)}{2300} = 0.27 \text{ micromho}$$

It has been found that CO_2 can be eliminated by this method but that last traces of NH_3 are found in the concentrated residues. The amount of residual NH_3 has been reported as varying from 0.03 ppm to 0.20 ppm (12). These residuals are, however, in the concentrated samples and when calculated to actual correction on the original sample, vary from 0.02 to 0.36 micromho. These corrected values are not excessively large and normally will not exceed 0.2 micromho.

For accurate work it is necessary to determine these residuals and make correction for them, but in the average run of commercial testing it is probable that the accuracy of sampling has not kept pace with the accuracy of the purity determination even when these corrections are not applied. There is little justification for reporting steam purities of less than one-half part per million, closer than the nearest tenth of a part. In most cases the presence of insoluble carryover equals if not exceeds the correction made for residual ammonia.

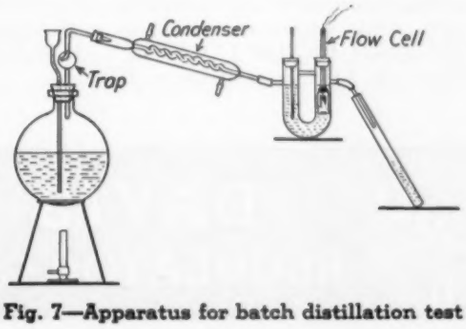

Fig. 7—Apparatus for batch distillation test

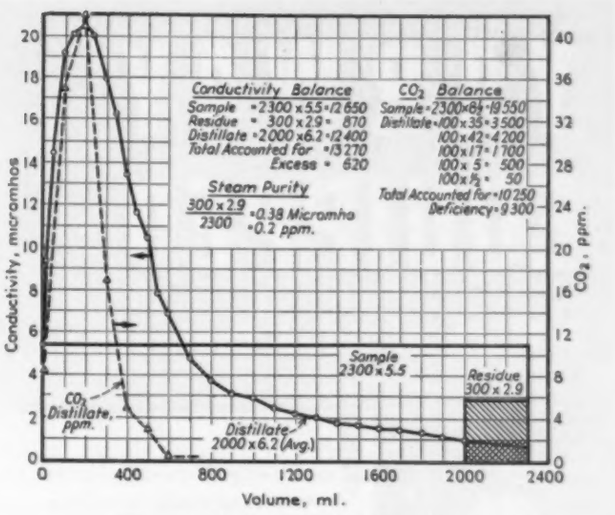
Conductivity Balance
Sample = 2300 x 5.5 = 12 650
Residue = 300 x 2.9 = 870
Distillate = 2000 x 6.2 = 12 400
Total Accounted for = 13 270
Excess = 620
CO2 Balance
Sample = 2300 x 8 = 19 550
Distillate = 100 x 35 = 3 500
100 x 42 = 4 200
100 x 17 = 1 700
100 x 5 = 500
100 x ½ = 50
Total Accounted for = 10 250
Deficiency = 9 300
Steam Purity
300 x 2.9 / 2300 = 0.38 Micromho = 0.2 ppm.
Sample 2300 x 5.5
Residue 300 x 2.9
CO2 Distillate, ppm.
Distillate 2000 x 6.2 (Avg.)
Conductivity, micromhos
CO2, ppm.
Volume, ml.

Fig. 8—Typical distillation test

Summary

Only acid and basic gases which combine chemically in solution to give ionized compounds affect conductivity measurements. An equilibrium exists between the amount of gas in combination, the amount in simple solution and the amount above the liquid as partial pressure. Elimination is based primarily on reduction in partial pressure which destroys the equilibrium and favors reduction of the amount of gas in ionized form. The more soluble the gas is, the less the amount of partial pressure to work on and the more completely must the partial pressure be eliminated to reduce the dissolved gas to negligible amounts.

Acknowledgment

In closing, the author wishes to express appreciation for the cooperation of the several investigators listed herein, who kindly furnished diagrams and subject matter entering into this paper.

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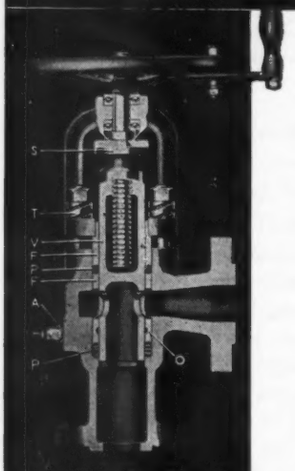

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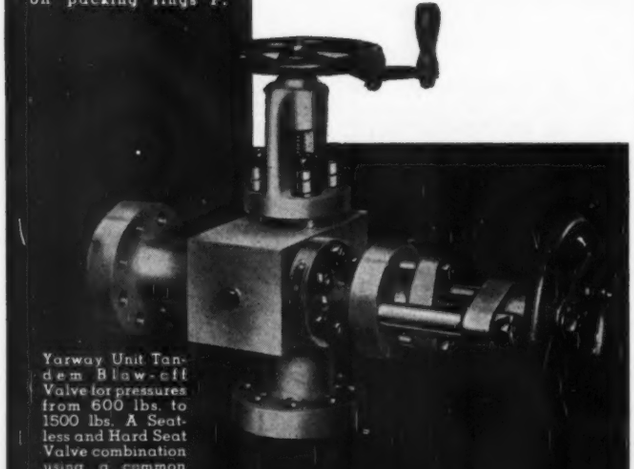

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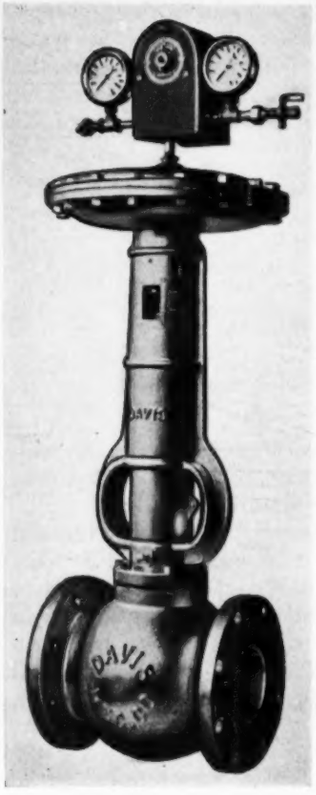

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NOTES ON SLAG REMOVAL

The following was prepared in response to an inquiry by a reader and it is believed that it may be of sufficient interest to some other readers to warrant publication. It briefly reviews what has been done to minimize slag accumulations and gives some high spots of current practice in slag removal from heavy-duty units without attempting to go into detail.—Editor

JUST as fleas are inherent with the canine species, slag accumulations appear to be an accepted nuisance in the operation of modern high-capacity boilers. The extent to which such slag may present a problem depends upon the percentage and characteristics of the ash in the coal, the load carried and the operating cycle. Although more prevalent when burning pulverized coal, slag may also be troublesome under certain conditions with stokers and is sometimes encountered in a particularly tenacious form when burning oil, where the oil contains considerable silica.

Operation at high capacity for long periods, such as may be called for under present conditions, may cause the slag to build up to the extent of interfering with heat transfer and producing excessive steam temperature, and perhaps high draft loss, unless means are taken repeatedly to remove the accumulations mechanically. On the other hand, if the operating cycle is such that full load operation is followed by several hours of light load, during the twenty-four, the furnace will be self-cleaning. A similar situation obtains where alternate firing of pulverized coal and natural gas is employed.

Numerous investigations have shown that the slagging properties of a coal depend, to a large extent, upon the interrelation between the mineral constituents of the ash, as well as the spread between the initial deformation and the fluid temperature of the ash; also, that with some coals it is possible to control the ash fusion temperature by controlling the acid-base ratio. While these investigations have been helpful in the selection of coals, the fact remains that other considerations often enter into the purchasing of coal and the slagging problem persists in many plants, although more effective means have been developed to cope with it.

During the last five or six years much experience has been gained in handling this problem in the operation of high-temperature, heavy-duty units and certain modifications in design and in operating procedure have assisted greatly in minimizing troublesome slag accumulations.

With slagging-bottom furnaces, which are now being used extensively for heavy-duty units where the coal has an ash fusion temperature of not more than 2600 or 2700 F, less ash passes through the boiler, superheater and economizer. The elimination of intermediate furnace-wall headers does away with a source of slag accumulations as does the elimination of refractories around burners and in other locations. Also, with bare metal walls the tendency of the slag is to reach a state of equilibrium after which it will run down in fluid state instead of building up. The much wider spacing of superheater elements, at the gas entrance side, with a corresponding reduction in gas velocities, has resulted in such ash as does accumulate being of a form that can be readily removed. Slag accumulations are less likely to occur on the convection boiler surfaces following the superheater and if they do, they are friable and can be readily removed by mass soot blowers. Finally, units are now usually arranged to permit access to the heating surfaces either by mass soot blowers or hand lancing from operating platforms.

With modern high-temperature, high-capacity units it is difficult to maintain the conventional multi-nozzle, rotary type of soot blower which is suitable for locations of relatively low temperature, such as economizers or the later passes of the boiler. Instead, for the more severe service in the region of high gas temperatures, the conventional type has given place to the mass blower of the retractable or telescopic type, the latter being particularly adaptable where surfaces at some distance within the setting are to be reached. Mass blowers are also effective for wall cleaning, with the jet directed along the wall, unless the slag is plastic or fluid in which case hand lancing is usually necessary.

Porous slag if allowed to build up will bridge over between tubes and produce excessive draft loss. It is readily removable by mass blowers. Practice varies widely as to the steam pressure employed in such blowers. The pressures range from 200 to 600 lb, although around 400 lb appears to be more common. The most effective pressure for the individual case is a matter of trial. Where the slag is of such a character that it becomes necessary to cool it in order to effect removal, highly saturated steam or water may be employed as the blowing medium.

With hand lancing some companies find water the most effective whereas others prefer compressed air, practice being about equally divided between the two mediums. When water is used care must be taken to avoid impingement on any refractory, headers, baffles or rolled joints where the chilling effects might produce cracking or leaky joints. Furthermore, the jet should be kept in motion. Although a few companies employ water lancing on superheaters without any bad effects, air seems to be generally preferred for this purpose.

The frequency of hand lancing depends on the load carried and the operating cycle of the unit. Where continuous high ratings are carried frequent lancing is usually necessary but if the heavy loads are followed by light loads for several hours it may not be necessary at all as the walls will then be self-cleaning.

According to operating company statements in the recent E.E.I. Prime Movers Committee report on Boilers and Combustion, the time required for slag removal varies from 2 hr per day per boiler to as much as the full time of one man per shift where conditions are particularly bad. For the average case, once per shift appears to suffice except during high sustained loads.

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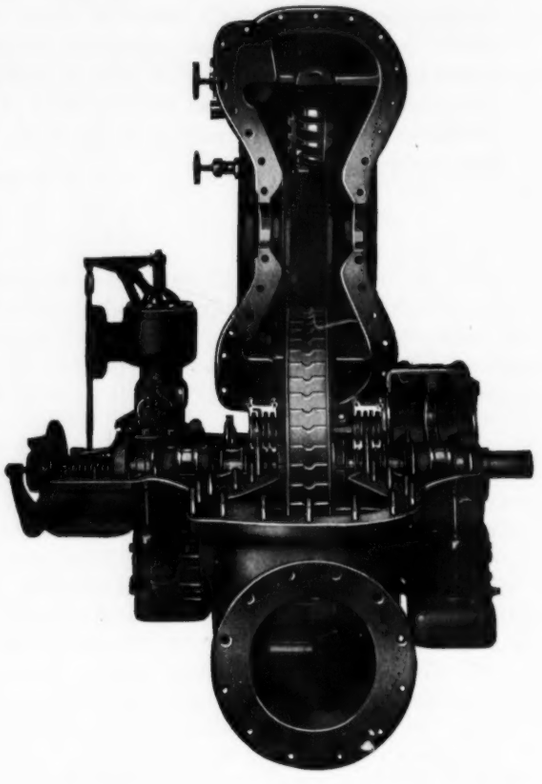

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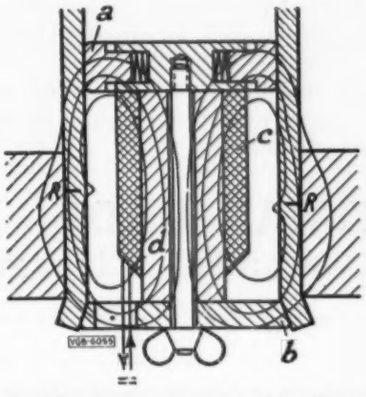
Magnetic Tests for Cracks in Boiler Tubes

Magnetic powder and oil have long been employed as a means for detecting cracks in metal, but experience in Germany has indicated that this method as ordinarily applied has certain limitations with respect to circumferential cracks in boiler tubes, chiefly because of difficulty in establishing a suitable magnetic field. The field must, if possible, be at right angles to the suspected crack and the sensitivity appears to be confined to a relatively shallow depth. Also, because of limited penetration, a-c magnetism was unsatisfactory and direct current was necessary.

The cracks were found to appear mostly in the tubes near the lower drums of bent-tube boilers, in the lower half of the rolled joints of the first and second rows of the



Sketch of magnet inserted within tube end to indicate cracks

steaming tubes and in the last row of the rear bank. They originated at the outer tube wall and it was necessary to locate them from the inside of the tube by means of a sufficiently strong magnetic field in a direction longitudinal with the tube.

Accordingly, a device as shown in the sketch was designed for this purpose and is said to be able to disclose cracks whose existence had not been suspected. It is described in detail in an article in *Die Wärme*, Vol. 63, No. 32, p. 269, which also shows photographic reproductions of cracks thus located and gives a tabulation of results attained.

The magnet, which is inserted in the tube end, has a fixed size of central core but can be fitted with top and bottom flanges suited to the size of tube. Referring to the sketch, *R* represents a circumferential crack, *a* and *b* are, respectively, the top and bottom flanges, *c* is the direct-current magnet winding and *d* the iron core. Twenty-four volts is employed from a rectifier, this voltage appearing most satisfactory as well as safe for the operator.

In operation the tube is thoroughly cleaned, the magnet inserted and, simultaneously with switching on the current, the rolled surface is sponged with the oil containing magnetic powder. Only after the oil has drained off is the magnet removed and one must be careful not to disturb the adhering powder. The time for making a test is about a minute.

You can bank on these Reliance Heavy Duty Valves for *leak-proof* gage service on High Pressures

● Here's a valve that won't "let you down" on toughest water gage jobs up to 2000 pounds. It's a valve you'll be proud of—made of forged steel, with stainless steel seat and floating disc; quarter pitch triple thread closes valve in one-third turn; spanner wrench packing nuts—super-seal metalastic packing; standard ASA welded blow-down flange. Slight variations in design are possible to accommodate different diameters of nipples and varying means of attachment under special requirements. Send details of your water column installation—write today for prices and further information.

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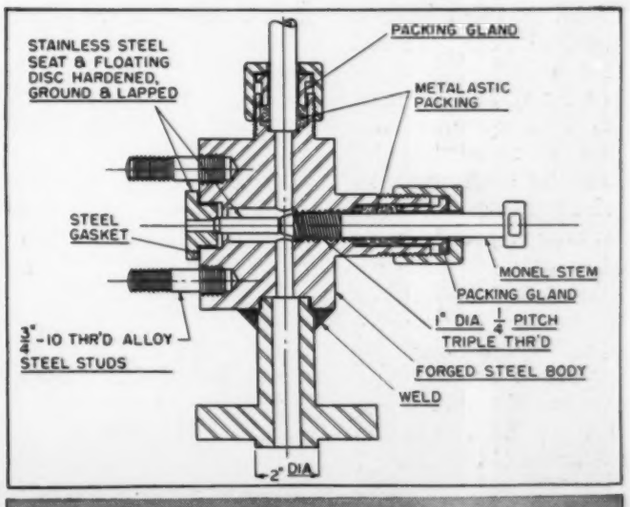


Reliance
TRADE MARK - REG. IN U.S. PAT. OFF.
Boiler Safety Devices since 1884

Pictured above is a common form of Sauerman scraper coal storage layout for areas of small or medium size. Steel back-posts are spaced at intervals around the outer boundary of the area and the scraper bucket is shifted to different sectors by moving the tail-block on a bridle cable stretched between the back-posts.

The picture below shows Sauerman scraper unit with tail-blocks mounted on a mobile tail tower. This type of installation is designed for handling a large tonnage of coal on a good-sized ground space. Generally, the tower is equipped with a motor and propelling mechanism and movement of the tower is governed by remote control from the scraper operator's station at the head end of the installation.

SAUERMAN

POWER DRAG SCRAPERS

Stockpile Coal at Lowest Cost

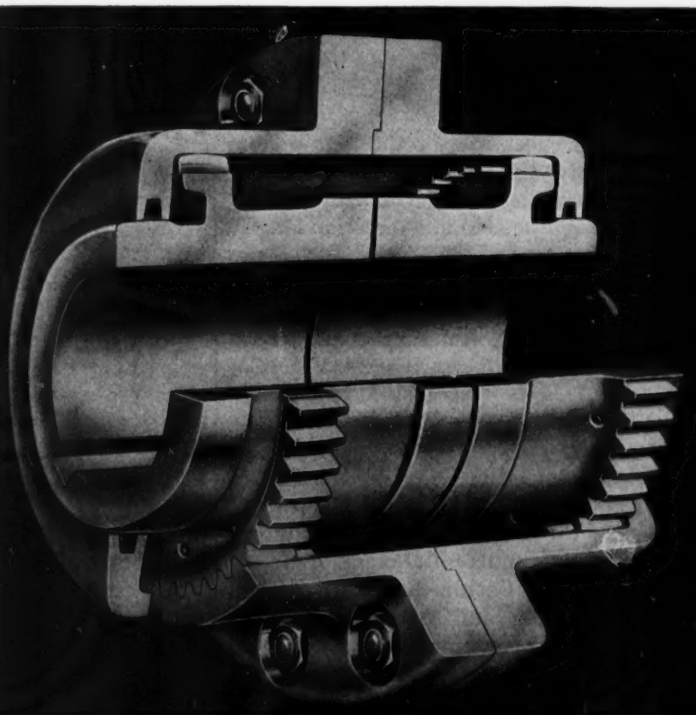
At hundreds of power plants, both large and small, Sauerman Power Drag Scrapers are storing and reclaiming coal at costs as low as 3¢ per ton handled. This economy is made possible by the rugged simplicity of the Sauerman equipment and its easy automatic operation.

An additional advantage of the Sauerman storage system is that the scraper piles the coal in well packed layers so that there is no opportunity for spontaneous combustion in the stored coal.

A catalog containing diagrams of coal storage layouts and useful operating data mailed free on request.

SAUERMAN BROS., Inc.
450 S. Clinton St. Chicago, Ill.

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

Million-Volt Radiography Applied to Boiler Drums

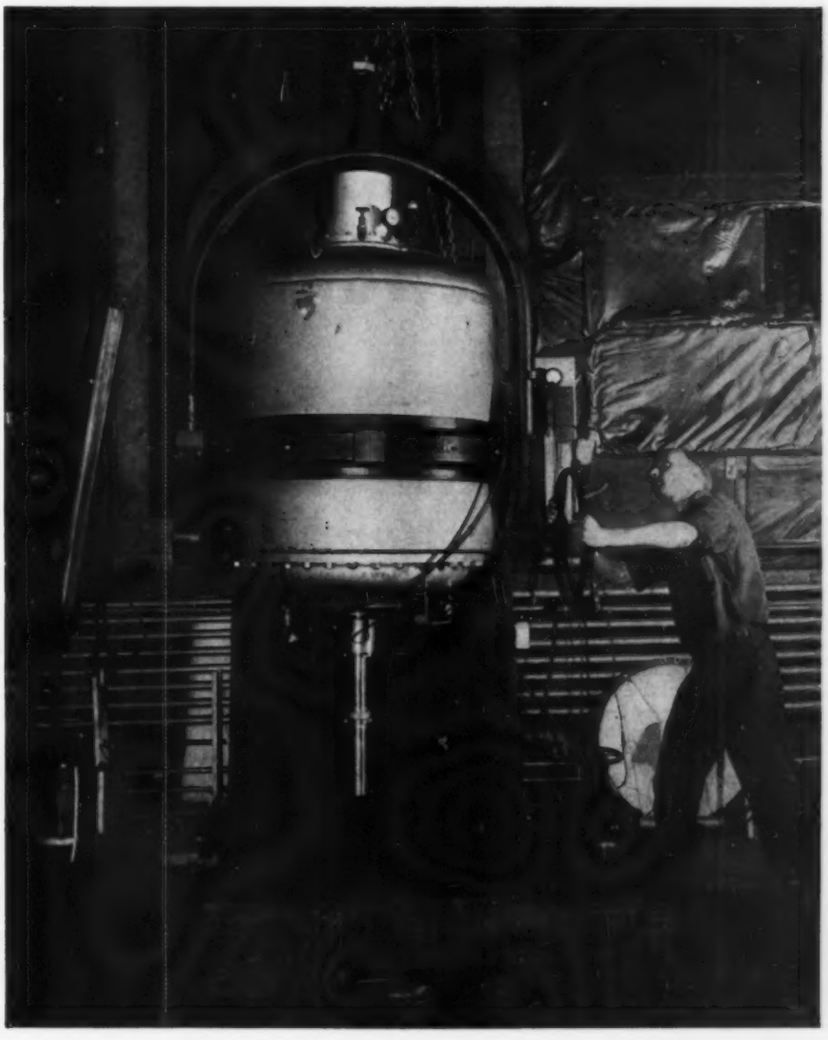
ONE of the first million-volt industrial X-ray units ever built is being installed by Combustion Engineering Company in its Chattanooga boiler shops. The development of an industrial unit of this rating was initially announced by the General Electric Company in December 1940, when they dedicated the installation at Schenectady of the pioneer million-volt industrial unit, as part of the program commemorating the fortieth anniversary of the G-E research laboratory.

The unit for Combustion Engineering, built by the General Electric X-Ray Corporation, exceeds by 600,000 volts the rating of the largest previous industrial units. It is capable of radiographing 8-in. steel in good commercial time and will effect a tremendous reduction in the time required for radiography of welded seams of the usual thickness required in boiler drums and other high-pressure vessels. The walls of the drums for modern high-pressure boilers range in thickness from about 3 in. to 5 in. or more. The new unit will radiograph 5-in. thick plate in about 5 minutes at a focal distance of 48 in., and 3-in. plate at the same focal distance can be penetrated in 48 seconds. With the 400,000-volt unit, the most practical focal distance for these thicknesses is 32 in., and at this distance the exposure time for the corresponding thicknesses are: 5-in. plate —135 min.; 3-in.plate—$2^1/_2$ min.

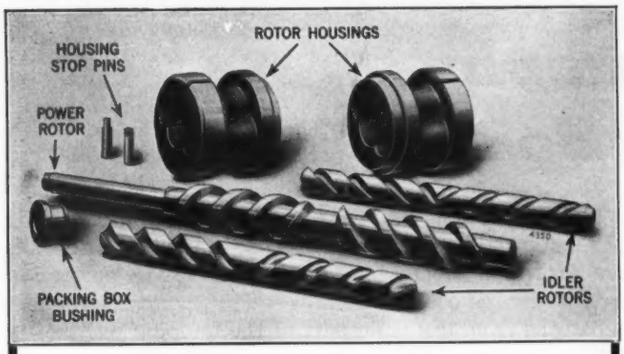
Thus a twofold time saving will be effected—the reduction in exposure time which increases rapidly with metal thickness (more than one hundred times as fast at $5^1/_2$ in.) and reduction in number of negatives because of the longer focal distance which can be used. The importance of the latter results from the large number of exposures required to radiograph the seams of big drums —several hundred per boiler in some cases—and the time consumed in setting-up for each exposure. Another important advantage is the superior quality of the negatives obtained which provide a wealth of sharp diagnostic detail even at maximum penetration.

The new unit is being installed in a separate building of substantial size built especially to house it. The walls are of 18-in. concrete to provide adequate protection against escape of stray X-rays. The operator's room is separated from the main part of the building by the full wall thickness. The unit itself consists of a resonant transformer within which is a coaxially mounted, multi-section, high-vacuum X-ray tube, both contained in a grounded steel tank and employing compressed gas (Freon) insulation. The X-rays are generated from a target mounted in the end of an extension chamber projecting out from one end of the electrically grounded tank. The unit is rated at one million volts and 3 milliamperes continuous current. A particularly spectacular aspect is that the unit produces energy equal to $90,000,000 worth of radium.

The addition of this unit to the five smaller X-ray units now installed in Combustion Engineering shops will assist materially in handling the company's heavy volume of defense work.



Operator adjusting position of original million-volt industrial X-ray unit at Schenectady works of General Electric Company. Combustion Engineering's million-volt unit is a duplicate.



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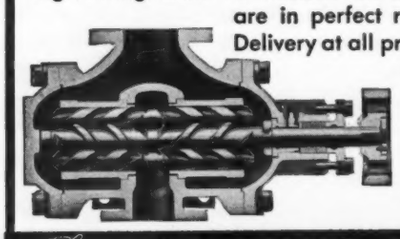
VALVES, GEARS, BEARINGS NONE

Internal parts of the *De Laval-IMO Oil Pump* are easily accessible, without removal from base plate or disturbing driving motor or turbine. The three moving parts are in perfect rotational balance. Delivery at all pressures and capacities is smooth and continuous, as from a piston moving steadily forward.



Ask for Catalog I-81.

IMO PUMP DIVISION

of the De Laval Steam Turbine Co., Trenton, N. J.

PROFIT BY

The Combustion Engineering Co.'s

EXPERIENCE

CAREYSTONE Corrugated Roofing selected for this building of The Combustion Engineering Co. at Chattanooga, Tenn.—230 ft. long, 100 ft. wide, 56 ft. high.

SPECIFY... Careystone ASBESTOS-CEMENT

CORRUGATED ROOFING

In the race for increased production, CAREYSTONE meets the call for speed. This unexcelled roofing and siding material—permanently combined Asbestos and Portland Cement—helps reduce "bottlenecks" caused by defense needs for metals.

Easily and speedily erected, CAREYSTONE Corrugated meets permanent as well as temporary needs, with little or no loss or waste when buildings are dismantled. Salvaged CAREYSTONE can be stored, sold, or re-used.

CAREYSTONE is fire-resistant and is widely used where acid and alkali fumes are prevalent. Contains nothing that can rust, rot or corrode. Its low first cost is practically the only cost—giving dependable service with minimum maintenance expense, year after year. For complete details, call the nearest Carey Branch Office or write Dept. 69.

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BOOK REVIEWS

Books here reviewed may be secured through Combustion Publishing Co., 200 Madison Ave., N. Y.

Steam for Industrial Processing and Power

Edited by E. Molloy

There are still a large number of industries such as brewing, dyeing, food canning, etc., in which steam is necessary for processing and where the use of steam power has a distinct advantage. It is for the engineers who are responsible for the operation of such industrial plants that this book has been prepared. A general description of process steam installations is given in Chapter 1, which also deals with the properties of steam, methods of heating, the use of dual-process steam, and the Ruth's Steam Accumulator. The following chapters cover such topics as Forced Draft for Industrial Boilers, Turbine and Condensing-plant Maintenance, Reducing Valves and Desuperheaters, Water Treatment, and Calorifiers and Water Treatment.

This book comprises a compact source of information, data and formula pertaining to small industrial plant operation, and it is generously illustrated with halftones, diagrams and charts. Size $5^1/_2 \times 8^3/_4$; 112 pages, including index; bound in dark blue cloth. Price $2.00.

Steam Engines and Boilers

Edited by E. Molloy

This book has been compiled for the use of engineers who are specially concerned with the operation and maintenance of a steam plant. The first chapter describes the principal types of steam engines and boilers in common use, and instructions are given on starting up and running a stationary plant. Chapter II, which deals with modern stationary steam boilers, closes with a brief description of the LaMont forced- and controlled-circulation boiler. The omission of a diagram of this system is a minor flaw in an otherwise excellent chapter. The two remaining chapters deal with pulverized coal firing and oil fuel burning.

The book contains 112 pages (including index) and is well illustrated with 115 line cuts and halftones. It is concisely written and replete with practical hints and useful information. Bound in dark blue cloth, size $5^1/_2 \times 8^3/_4$. Price $2.00.

Electric Current Consumption, Cost and Savings

Edited by Georges C. St. Laurent

A few of the topics discussed in this book are as follows: Electric Current Rates; Diesel Engines for Hotels; Guest Room Air Conditioning Units; Fluorescent Lighting; Electric and Gas Cooking; Economy in Lighting; Savings on Elevator Operation; Central Cleaning Plant and Small Portable Units. This is the first time information of this kind has been published for the hotel field.

Statistics show what effect various factors have on the amount of electric current consumed, such as size of hotel, amount of occupancy, amount of air conditioning, number of elevators and the operation of a kitchen and laundry.

The price of the book is $1.50.

The Coal Situation Reviewed

The Bituminous Coal Division of the Department of the Interior is concerned over a possible consumers' coal shortage this fall in the face of national defense and winter heating demands. This view is based on the results of a recent survey which showed:

1. An annual increase of over ten per cent in coal requirements is estimated, with over 500 million tons needed by the nation in 1941, compared with the 1940 production of 453 million tons.
2. A 56-per cent reduction in consumers' coal stocks following recent strikes which cut reserves at points of use from approximately 50 million to 22 million tons.
3. A cut of 58 per cent in surplus railroad cars, from June 30, 1940, to June 14, 1941, indicating a possible car shortage.
4. The necessity for increasing the weekly production over ten per cent and attaining for sustained periods this fall a weekly output of 11 million tons compared with an average of 8 million tons a year ago or 10 million tons in June 1941.
5. The increasing demand for bituminous coal resulting from changes from oil to coal, because of the present oil situation along the Atlantic Seaboard.
6. Difficulty, in the face of defense production, of obtaining essential mining machinery because of present increasing mechanization in mining practices.

It is pointed out that car shortages are most likely to occur next September and October when the peak in seasonal influence on coal production will begin to be felt and when heavy shipments to lower Great Lakes ports will still be in progress. However, after the Great Lakes freeze over these shipments will cease and many cars will be released. This will be a factor in helping to meet the peak in seasonal requirements, although increasing defense production will create a heavy demand for such cars for hauling bulk materials.

In addition to the possibility of transportation difficulties, Coal Division economists report that there is no guarantee that mine production will be able to meet the demand for all grades and sizes of coal. At the present time such shortages are confined to certain special-use coals.

Because of the foregoing situation, the coal industry, with the co-operation of Government Defense Agencies, is conducting an intensive campaign in an effort to induce consumers to lay in sufficient stocks of coal before fall as a means of relieving the peak in transportation requirements.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1941 Water Tube		1940 Water Tube		1941 HRT Type		1940 HRT Type	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.....	170	968,275	62	285,042	89	123,459	51	68,639
Feb.....	102	896,763	54	386,356	81	104,622	47	51,474
Mar.....	141	988,927	56	438,980	86	89,324	51	58,529
April.....	159	802,993	89	476,135	129	151,636	56	50,356
May.....	134	850,659	101	663,721	114	154,964	75	84,094
June.....	141	743,762	150	814,210	114	134,880	110	122,026
Jan.-June Inclusive	847	5,251,379	512	3,064,444	613	758,885	390	435,118

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period January to June (incl.) 1941, 53,219,000 lb per hr; in 1940, 32,689,000 lb per hr.

†Mechanical Stoker Sales

	1941 Water Tube		1940 Water Tube		1941 Fire Tube		1940 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.....	77	41,975	24	10,770	94	14,036	104	14,745
Feb.....	60	27,736	31	10,729	117	14,774	118	17,862
Mar.....	69	31,342	35	17,460	146	21,552	76	12,717
April.....	75	34,882	36	14,554	147	20,555	87	15,123
May.....	90	43,971	73	30,930	144	19,267	88	11,402
June.....	136	50,896	65	15,772	264	42,619	153	21,736
Jan.-June Inclusive	507	230,802	264	100,215	912	132,803	626	93,585

† Capacity over 300 lb of coal per hr.

Pulverizer Sales

	1941 Water Tube			1940 Water Tube			1941 Water Tube			1940 Water Tube		
	No.		Lb	No.		Lb	No.		Lb	No.		Lb
	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr
Jan...	39	—	462,990	10	—	214,250	—	1	1,000	1	—	600
Feb...	42	4	734,200	15	1	186,935	—	—	—	1	2	2,800
Mar...	29	3	669,700	17	1	317,800	—	—	—	—	—	—
April..	17	8	435,740	26	5	270,500	1	—	2,800	—	—	—
May..	54	10	777,320	30	5	447,450	—	4	7,000	—	—	—
June..	28	24	523,540	21	2	360,270	—	1	1,000	—	—	—
Jan.-June Inclu.	209	49	3,603,490	119	14	1,797,205	1	6	11,800	2	2	3,400

(N)—New Boilers; (E)—Existing Boilers.

MORE H.P. FROM SAME BOILER

Rebaffling the Beco-Turner way results in greater capacity from water tube boilers. Each job is scientifically designed to increase heat transfer by increasing the active tube area. Your existing boiler can be rebaffled to produce the increased steam demands of National Defense requirements.

Ask for Beco-Turner Catalog showing typical installations and details of construction.

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1820 KINGSBURY ST., CHICAGO, ILL.

BECO-TURNER

No Cracks . . . No Leaks

The Beco-Turner expansion joint assures tightness. The baffle is gas tight when installed and remains gas tight because the expansion joints permit movement throughout the baffle without danger of cracks.

BAFFLES

ROTO
Gives You the POWER to Clean Tubes FASTER

Model 112 air-driven motor with swing-frame head

The new type boilers now being built present new problems in tube cleaning—new demands for rugged dependability. Roto is proud to be consulted by so many leading boiler, condenser and heat exchanger manufacturers on their tube cleaning problems. For obvious reasons, no design leaves the drafting board until some way is found to clean every tube in it.

The design of Roto Tube Cleaners is constantly being improved to keep pace with the demands for more power to clean tubes faster and more thoroughly. We would be glad to share our 30 years' specialized experience in helping you to get better tube cleaner performance.

MODEL 112
AIR-DRIVEN
MOTOR WITH
SWING-FRAME HEAD

The ROTO Company 145 Sussex Ave. Newark, N. J.

ROTO JUNIOR cleans tubes as small as ½" I. D.

National Defense Exposition to Open in September

With a view to focusing public attention on the necessity for speeding production by bringing all available facilities into the defense program, it has been decided to hold a National Defense Exposition at the Grand Central Palace, New York, from September 20 to October 18. It is planned to educate the public on the subject through exhibits and graphic demonstrations of its part in the program and to offer an opportunity to manufacturers to show how they are cooperating. All profit, above expenses, will be divided between the United Service Organizations and the Office of Civilian Defense.

Much new defense equipment now being turned out by industrial plants, such as field guns, machine guns, anti-aircraft guns, mechanized armored cars, as well as certain naval exhibits, it is expected, will be on view.

A feature of the opening week will be a "Defense Clinic", indorsed by the O.P.M. This will place emphasis on the civilian side of the problem and show how civilians are being organized to cooperate with federal and city authorities and with the Army and Navy; also, how defense works in case of an air raid, how to handle incendiary bombs and how to apply first-aid treatment. In this connection sound films of air raids and combats that have taken place in England and on the Continent will be employed.

Guiding the venture is a general advisory committee of over forty prominent citizens, industrialists and representatives of the Army and Navy under the chairmanship of George A. Sloan, Commissioner of Commerce for New York City.

Correction—On page 42 of the July issue a typographical error appeared in the title of Col. H. S. Bennion. It should have read, "Vice President and Managing Director, Edison Electric Institute." Our apology is due to Colonel Bennion for failure to detect the error before the issue was off the press

Advertisers in This Issue

Air Preheater Corporation, The..... 11
American Blower Corporation..... 4-5
E. B. Badger & Sons Company..... 16
Buell Engineering Company, Inc..... 18
Philip Carey Mfg. Company, The..... 42
Chesapeake and Ohio Lines.....Fourth Cover
Combustion Engineering Company, Inc.....
.....Second Cover, 8 and 9
Crosby Steam Gage and Valve Company..... 13
Davis Regulator Company..... 36
De Laval Steam Turbine Company..... 42
Diamond Power Specialty Corporation.....Third Cover
Elliott Company..... 24
General Electric Company..... 6
Globe Steel Tubes Company..... 17
Ingersoll-Rand Company..... 14
Johns-Manville..... 7
Koppers Coal Company, The..... 15
Northern Equipment Company..... 2
Plibrico Jointless Firebrick Company..... 43
Poole Foundry & Machine Company..... 40
Prat-Daniel Corporation..... 3
Reliance Gauge Column Company, The..... 39
Research Corporation..... 10
Roto Company, The..... 44
Sauerman Bros., Inc..... 40
Steel and Tubes Division, Republic Steel Corporation 12
Terry Steam Turbine Company, The..... 38
Underground Steam Construction Company..... 16
Yarnall-Waring Company..... 36